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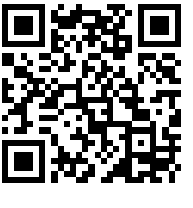

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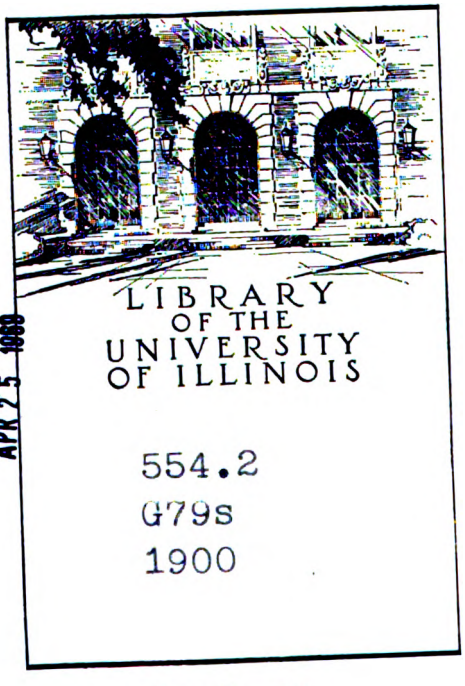

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MEMOIRS OF THE GEOLOGICAL SURVEY.

SUMMARY OF PROGRESS

OF THE

GEOLOGICAL SURVEY

OF THE

UNITED KINGDOM

FOR

1900.

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PREFACE.

THE present volume has been prepared for the purpose of making known the general plan of work and the state of progress of the Geological Survey of the United Kingdom during the year 1900. The nature and some of the more interesting or important features of the various lines of investigation in the field, the office, the laboratory, and the museum, are briefly described. As far as possible, the account of the work of each member of the staff is given as reported by himself. In such narratives, even where the Editor exercises to the full his functions of excision and condensation, it is difficult to avoid what may seem to be a superfluity of local detail. It must be remembered, however, that the great value of much of the work consists in this very detail, which, even where it may have little interest for the general reader, is appreciated by those to whom new observations in districts known to them are welcome.

The general distribution of the mapping in each of the three kingdoms is in the following pages first briefly sketched. Thereafter the additions made by the staff last year to our knowledge of each of the geological formations in the country are given in stratigraphical order, from the oldest gneiss up to the most recent deposits. The most remarkable of these additions is undoubtedly the discovery of a large volcanic vent in the Isle of Arran, in which have been preserved masses of Rhætic, Liassic, and Upper Cretaceous strata. It is thus possible to determine beyond reasonable doubt that the later igneous rocks of that island are of Tertiary age, to show that Mesozoic formations once stretched into the basin of the Clyde, and to demonstrate how stupendous has been the denudation of the general surface of the country since the Cretaceous period.

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Another important and suggestive observation is the relation discovered to exist between some younger granites of the Southern Highlands and the vents of the Lorne volcanic region. As these vents belong to the time of the Lower Old Red Sandstone, the granites which invade them cannot be older than that time, but probably belong to the remarkable series of granite extrusions which in the British Islands intervened between the close of the Upper Silurian and the beginning of the Upper Old Red Sandstone periods.

The Petrographical work of the Survey is then briefly described, and a summary is thereafter given of an investigation of the remarkable assemblage of eruptive rocks which has been detected in Assynt, and of the metamorphism induced by them on the surrounding dolomites.

The Palæontological observations made at the Museum of Practical Geology, and at the Survey Office in Edinburgh, are next shortly epitomised, and attention is called to a few of their more important features. Brief allusion is likewise made to the continued applications received at the several offices of the Survey from the general public and from Government departments and Local Boards for advice and assistance in matters where a knowledge of geology, and more especially of the geological structure of particular districts, is involved.

A list is given of the maps, sections, memoirs, and other publications issued by the Geological Survey during the past year, and now in course of preparation, together with a statement of the non-official contributions to science made by members of the staff.

In the Appendices will be found catalogues of types and figured specimens from British Pliocene and Pleistocene, and Devonian strata in the Jermyn Street Museum. These are the second and third instalments of the series of such catalogues, which, as announced in the last *Summary of Progress*, it is intended to prepare and publish.

As I retire to-day from the Public Service in which I have spent upwards of forty-five years, I may be allowed, as my

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closing official act, to express the satisfaction with which I hand over the administration of the Geological Survey and Museum to my friend and colleague Mr. J. J. H. Teall, and the confidence with which I look forward to the increased strength and efficiency of the institution.

ARCH. GEIKIE,
Director-General.

Geological Survey Office,
28, *Jermyn Street, London,*
February 28th, 1901.

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SUMMARY OF PROGRESS

OF THE

GEOLOGICAL SURVEY

FOR 1900.

PART I.—FIELD-WORK.

I.—GENERAL DISTRIBUTION AND STATISTICS OF THE STAFF.

1.—ENGLAND AND WALES.

In continuation of the arrangement made in the summer of 1899, the immediate charge of the Staff of the Survey in England and Wales has been in the hands of MR. H. B. WOODWARD, F.R.S. He has been chiefly engaged at the head office, but has from time to time visited the officers in the field. The pressure of other duties has for some years past made it impossible for him to resume the mapping of the Jurassic rocks of the north-west Highlands, in which he had made some progress. As it was necessary to complete this work in order to allow of the publication of the maps, and as none of the Staff in Scotland possesses the requisite acquaintance with the Jurassic formations to be able to continue MR. WOODWARD'S mapping, it was deemed best that MR. C. B. WEDD should be detailed for the purpose from his district in Staffordshire, and that Mr. WOODWARD should start him on the Jurassic ground in Skye—an arrangement which has proved entirely satisfactory.

As stated in previous *Summaries of Progress*, the field-work of the Survey in England and Wales now consists in the revision of the published maps, and in the resurvey of the Coalfields and of those counties where the Drifts were not originally mapped. The general distribution of the Staff has remained nearly the same as described in the last *Summary*. During the summer, however, it was found necessary temporarily to transfer three members of the English Staff to complete or expedite the

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field-work in Scotland. Mr. S. B. Wilkinson, who is now stationed in Cornwall, was for this reason engaged for part of the season in finishing his mapping of the Island of Jura; Mr. J. B. Hill, also stationed in Cornwall, was likewise employed in pushing forward the Survey of Argyllshire in continuation of his previous work in that county, while Mr. Wedd undertook, during two of the summer months, the Jurassic mapping above referred to. These interchanges for the advancement of the field-work in Scotland are further referred to on pp. 4 to 6. The withdrawal of these officers for part of the year has necessarily helped to reduce the area surveyed in England and Wales.

In the district of Berkshire, Buckinghamshire, and Oxfordshire, Mr. J. H. Blake, from his station at Oxford, has surveyed a tract of 25 square miles, including 101 miles of boundary-lines, of which 79 relate to superficial deposits.

In Cambridgeshire and Huntingdonshire, Mr. Wedd, who was detailed for this special purpose, surveyed the Corallian rocks in order to complete a map, and traced there 34½ miles of new boundary-lines in these formations.

The revision and resurvey in the region embracing Cheshire, Derbyshire, Leicestershire, Shropshire, and Staffordshire have been, as hitherto, supervised by Mr. Fox Strangways, with whom have been associated Mr. George Barrow, Mr. Walcot Gibson, Mr. T. I. Pocock, and Mr. Wedd. An area of 140¾ square miles has there been surveyed, including 970½ miles of boundary-lines, whereof 533 belong to the Drifts. For reasons which will be more fully stated further on, Mr. Barrow was able to give only a short time in the early summer to field-work in the Staffordshire district when he mapped a tract of 4½ square miles and traced 10 miles of boundary among the solid rocks. Besides mapping upwards of 60 square miles of this district, Mr. Gibson and Mr. Wedd had to spend a considerable amount of time in the laborious duty of examining mining plans and sections in the colliery offices of North Staffordshire. Mr. Gibson has now gained an acquaintance with the details of these Midland coal-pits, which is of great practical value in regard to questions that arise as to the extension and identification of the several subdivisions of the Coal-measures under the New Red Sandstone of that part of England. To the east and south-east of Macclesfield a tract of ground, nearly 30 square miles in area, of much practical importance, but considerably complicated by faults and folds, and requiring a good deal of time for its examination, has been mapped by Mr. Pocock. In addition to the general supervision of the field-work of his colleagues, Mr. Fox Strangways has himself mapped a tract of 45 square miles, which embraces 324 miles of boundary-lines, whereof 44 are those of the solid rocks and 280 those of the superficial formations. He has completed the survey of Sheet 156, and has written a memoir for the adjacent Sheet 155, which has been published.

In Cornwall and Devonshire the field-work has proceeded along

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the same lines as in the last few years. MR. USSHER mapped 22¾ square miles, including 140 miles of geological boundaries. His time, however, has been partly taken up in the preparation of a memoir on a part of Devonshire surveyed by him, as well as of other memoirs, now in progress, relating to the new series of maps, and partly in tracing fresh boundary-lines in areas already surveyed. MR. WILKINSON has completed an area of 43½ square miles in the south-west of Cornwall, including 110 miles of boundary; but, as already stated, he was transferred for a portion of the year to complete work in Scotland. MR. HILL'S return of field-work in Cornwall amounts to 30 square miles, surveyed from his station at Falmouth, and includes 156 miles of geological boundary. But he also, as already stated, spent a considerable part of the working season in completing the mapping of some of the ground in Argyllshire on which he was formerly engaged.

In Dorset and Wiltshire the field-work has been carried on under the superintendence of MR. CLEMENT REID, with whom MR. E. E. L. DIXON has been associated. The area surveyed in these counties amounts to 39¼ square miles, and includes 252 miles of boundary-lines, of which 73 belong to the drift deposits. Besides his duties in the field, MR. REID has taken charge of the work of this office during MR. WOODWARD'S absence, and his assistance has been of much service in preparing memoirs for the printer, in answering public inquiries, and above all, in the elaboration of a scheme for the production of maps by colour-printing, to which reference will be made further on. It should be mentioned that the area examined by MR. DIXON was considerably larger than that which appears in the returns as surveyed by him, inasmuch as he had to trace fresh boundary-lines required in the ground formerly mapped by MR. JUKES BROWNE.

In the revision of the geology of Sussex, MR. G. W. LAMPLUGH has surveyed an area of 42½ square miles, including 203 miles of boundary, of which 50 belong to the superficial deposits. But in addition to this mapping, his time and attention have been required to gather the geological results that might be obtainable from the sinking for coal now being carried on at Dover, while he has also necessarily been much occupied in correcting the proofs of his Memoir on the Geology of the Isle of Man.

In South Wales the re-survey of the coal-field has been continued under the superintendence of MR. A. STRAHAN, with the assistance of MR. R. H. TIDDEMAN and MR. T. C. CANTRILL. The area surveyed by these officers during last year amounts to 90¼ square miles, with 609 miles of boundary-lines, whereof 292 or nearly half have reference to the various superficial deposits. In connection with the field-work in this region, DR. W. POLLARD spent a short time in the peninsula of Gower resuming and continuing his investigation of the dolomitisation of the Carboniferous Limestone.

The total area of ground surveyed during the past year in

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England and Wales amounts to 434 square miles, and the length of boundary-lines traced is 2,575 miles, of which 1,079 belonged to the superficial deposits. This considerable diminution of area has arisen from several causes, of which the chief has been the necessity of overtaking the accumulation of indoor work which had to be pushed forward in order to permit the completion of certain maps and memoirs. A large part of this work has been cleared off, and it is anticipated that the mapping will now proceed at a quicker pace.

It will be observed that while there has been a falling off in the total area surveyed, the field-work has at the same time increased in complexity, for every square mile mapped has necessitated the tracing of six miles of boundary-lines.

2.—SCOTLAND.

The provisional arrangement referred to in the last *Summary of Progress*, by which the immediate supervision of the Survey of Scotland was placed in the hands of MR. JOHN HORNE, F.R.S., has been continued. MR. HORNE has not only undertaken the general charge of the Scottish branch of the establishment, but, during a part of the year, has resumed his field-work in Inverness-shire, with the view of clearing off some of the outlying portions of the ground already surveyed by him.

The only changes in the staff in Scotland are the appointment of MR. CECIL B. CRAMPTON, M.B., C.M., as an Assistant Geologist, who entered on his duties in April last, and the promotion of MR. L. W. HINXMAN, B.A., to be "Acting Geologist" until the re-organisation of the service has been completed and he can be placed on the permanent list.

The amount of field-work returned for the past year has fallen somewhat below the average, owing partly to MR. BARROW'S serious ill-health, which necessitated his retirement from the field after a period of only three weeks; partly to delays unavoidably arising in the completion of the mapping of the Island of Arran, which, though the area still to be surveyed amounted only to 6¼ square miles, involved the re-examination of certain complicated tracts consequent upon important recent discoveries; and partly to MR. GUNN'S earlier return to the office for the purpose of finishing the dry proof of Sheet 21 by the end of December.

In Aberdeenshire, which embraces a small part of the area surveyed by MR. HINXMAN, one quarter of a square mile and 26¾ miles of boundary are reported by him; and in the same county MR. CUNNINGHAM CRAIG mapped 26¾ square miles with 205½ miles of boundary.

In Argyllshire, the survey of the Island of Jura was completed, of which 6½ square miles with 51 miles of boundary were mapped by MR. PEACH; and 6½ square miles with 59 miles of

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boundary by MR. WILKINSON. From Oban as a centre, MR. SYMES surveyed 31½ square miles, and traced 190 miles of boundary. In the same county, MR. WILSON mapped 17½ square miles with 61 miles of boundary; MR. HILL, 10 square miles with 124 miles of boundary; and MR. KYNASTON, 53 square miles with 273 miles of boundary.

In the county of Banff, MR. CUNNINGHAM CRAIG surveyed 4 square miles with 5½ miles of boundary.

In the Island of Arran, MR. GUNN mapped 6¼ square miles, and traced 111 miles of boundary.

In the county of Caithness, from Wick as a centre, MR. PEACH surveyed 41 square miles with 101 miles of boundary, and DR. CRAMPTON 44½ square miles with 38 miles of boundary and 6½ miles of coast line.

In Dumbartonshire, MR. CUNNINGHAM CRAIG traced 21 miles of boundary in ground previously surveyed.

In the county of Inverness, between Strath Nairn and the valley of the Findhorn at Tomatin, MR. HORNE surveyed 21 square miles with 94 miles of boundary. In the west part of the same county, south of Loch Hourn, MR. CLOUGH completed an area of 24½ square miles with 224 miles of boundary. In the central and eastern parts of the county, MR. HINXMAN mapped 28¼ square miles with 119½ miles of boundary; and in the Fort William District, MR. GRANT WILSON surveyed 18 square miles with 88 miles of boundary. In the island of Skye, MR. HARKER mapped 13$\frac{3}{16}$ square miles with 216 miles of boundary, and MR. WEDD 6 square miles with 37$\frac{5}{8}$ miles of boundary.

In Perthshire, MR. BARROW, before he was prostrated by illness, mapped 3 square miles with 20 miles of boundary; MR. GRANT WILSON surveyed 22 square miles with 74 miles of boundary, while MR. CUNNINGHAM CRAIG traced 135 miles of new boundary on ground previously surveyed.

In Ross-shire, MR. PEACH surveyed 12 square miles with 76 miles of boundary; MR. CLOUGH, 7$\frac{15}{16}$ square miles with 99 miles of boundary; and MR. HINXMAN, 27 square miles with 168 miles of boundary.

The total area surveyed in Scotland during the year has been 430$\frac{5}{8}$ square miles, and the total length of boundary-lines traced amounts to 2,618$\frac{1}{2}$ miles.

The Director-General paid a series of visits of inspection of the field-work in Scotland. In Strath Nairn he had an opportunity of seeing some of the exceedingly interesting recent work of MR. HORNE in that district. Thence he went on to Skye, and saw a portion of MR. HARKER'S mapping in the Island of Scalpay. On the southward journey he took occasion to halt in the Perthshire Highlands, where in company with the District Surveyor MR. PEACH, and MR. GRANT WILSON, he inspected a part of the ground round Shiehallion, where some additional lines are needed; and also visited, with MR. CUNNINGHAM CRAIG, a portion of the area between the valleys of the Tay and the Tummel, on which that officer has recently been engaged. Before returning to headquarters he spent a week in Arran and

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saw with MR. GUNN the evidence of some of the remarkable discoveries which MR. PEACH, MR. GUNN, and MR. MACCONOCHIE have recently made in the island.

3.—IRELAND.

The field-work has been continued along the same lines as during the last few years. MR. NOLAN, owing to a rheumatic affection which incapacitated him from hill climbing, was prevented last year from continuing his revision of the Drift on which he has been engaged for several years.

MR. EGAN and MR. MCHENRY completed their revision of the Silurian rocks of Wicklow and Wexford. The former of these two geologists found himself early in September unequal to the fatigues of field-work, and had to return to the office. Having suffered serious injury from a car-accident, in which the Director-General and MR. MCHENRY were also involved, he had never thereafter regained his health and strength. He struggled with his weakness during the early half of last summer in the field, but was then compelled to take to indoor employment. Internal complications traceable to jaundice, arising from the effects of the accident, eventually assumed a malignant form, and finally carried him off on the 6th January. His gentle disposition made him everywhere a favourite, and his long and assiduous service to the Survey deserves hearty recognition.

MR. MCHENRY pushed the revision work in County Wexford until he joined up lines with MR. KILROE. Later in the year he was engaged with MR. SEYMOUR in a revision of the Silurian and igneous rocks to the north and to the south of Dublin, and of the numerous dykes along the southern coast of County Down.

MR. KILROE completed the revision of 216 miles of Silurian ground in the counties of Kilkenny, Wexford, and Waterford.

MR. SEYMOUR has studied and reported on 228 rock-slides, and has had 119 new slices prepared and added to the Irish collection, which now numbers 2,470. Besides these specimens he has examined and named a series of eighty slices which already existed in the collection but had not been determined. Of the rock-slides studied and reported on by him 115 were sent to him from Scotland, as it was impossible to find time for their study in the Petrographical Department at Jermyn Street. MR. SEYMOUR likewise at various times went to the field for the purpose of assisting the surveyors in the determination of the petrographical character of the rocks, and of gaining useful information for himself in regard to the relations of the masses in the field.

MR. CLARK, the fossil-collector, was occupied in the counties of Meath, Dublin, Wicklow, Kildare, Wexford, and Waterford, from which he obtained a large series of fossils and of rock specimens for the illustration of the new edition of the maps and the improvement of the Survey collections in the Museum of Science and Art in Dublin.

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During a tour of inspection in Ireland the Director-General took occasion to visit some critical sections in the counties of Wicklow and Wexford with MESSRS. EGAN, MCHENRY, and SEYMOUR, and arranged as to the way in which the rocks were to be mapped. He likewise spent some days in the county of Waterford with MR. KILROE and MR. SEYMOUR, giving attention more particularly to the coast-sections and deciding on the principle to be followed in the final mapping of that complicated region.

The chief scientific and economic results of the field-work of the Survey in the three kingdoms will now be given in stratigraphical order, beginning with the oldest geological formations.

Pre-Cambrian.

ROSS-SHIRE.

From Aultguish, between Garve and Ullapool, MR. B. N. PEACH continued the mapping done by him in former years. The prevalent rocks which he examined in this district belong to the type of "Moine schists" or "quartzose flagstones." They are essentially granulitic quartz-schists, with varying quantities of felspar, muscovite and biotite. Muscovite-biotite-gneiss, a more or less matted aggregate of biotite and muscovite, with granulitic quartz and felspar, and in places granitic knots of quartzo-felspathic material, occurs in belts among the "Moine schist." Augen-gneiss, or foliated porphyritic granite, occupies an area of about 3 square miles, making up part of the well-known mass of Inchbae. A few small outliers of Old Red Sandstone and Conglomerate also occur in the eastern part of the area. Mr. B. N. Peach.

"Moine schists" and "Muscovite-botite-gneiss," which make up three-fourths of the area, may be looked on as the country-rocks. As these rocks are continuous with those already noticed in previous Reports,* a full description of them need not be given here. It is only necessary, therefore, to repeat that the rocks are for the most part isoclinally folded, with the limbs of the folds dipping eastwards. In spite of this deceptive appearance of an upward succession towards the east, it can be demonstrated that the same beds are folded upon themselves so rapidly that they extend over broad belts of country measured across the strike. In the eastern part of the area the long axes of the folds, and consequently the strike of the strata, are from N.N.E. to S.S.W., while in the western part the strike is N. and S., and sometimes N.N.W. and S.S.E. It is towards the western limit of the area that thin belts of Muscovite-biotite-gneiss occur, which are continuous with belts already traced through the ground to the south from near the head of Loch Luichart, where the evidence is in favour of the belief that the separate belts belong to a single band appearing in different folds, and separated into isolated portions by denudation.

* *Summary of Progress* for 1898, pp. 7-9; and for 1899, p. 7.

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Mr. B. N. Peach.

Of the well-known mass of intrusive Augen-gneiss or foliated porphyritic granite at Inchbae, about 3 square miles come into the district surveyed by MR. PEACH last year. The general character of this rock, together with its behaviour to the other schists which have already been described,* are well displayed in this district. The rock here also becomes finer grained, loses its porphyritic crystals near its junction with the schists, and sends out apophyses which penetrate the schists in the form either of sills that conform more or less to the original bedding planes of the schists, or of dykes that cut these planes. The granite appears to have produced a certain amount of contact alteration in the schists, though this early metamorphism is now masked in part by the structures that have been induced both in granite and schist by the pressure to which they have been alike subjected, and to which in great part, if not wholly, their present crystalline condition is due. In tracing the boundary-line of augen-gneiss it became apparent that the granite over a wide area lies in contact with the same band of rock, and that great irregularity of the boundary between them has been caused by the effects of denudation upon a highly plicated line of junction which displays a succession of isoclinal folds. Further, the available evidence supports the inference that in the area which has been mapped only a single line of contact is exposed, viz., that along the upper surface of the granite. The intrusive mass has, therefore, in all probability the form of a sheet or sill the bottom of which is not here laid bare.

Mr. C. T. Clough.

The crystalline rocks in the west of Inverness-shire between Loch Duich and the hills of Knoydart are undergoing examination by Mr. C. T. CLOUGH, who reports that most of the area which has been surveyed near Loch Duich is composed of rocks that probably belong to the Lewisian gneiss, but that siliceous granulitic schists belonging to the "Moine series" are mixed and repeatedly folded with them. The axial planes of most of the folds incline E. or S.E.

Of the many types of rock referred to the Lewisian gneiss the following are among the most noteworthy:

1. Marble with silicates of lime and magnesia.
2. Eclogite.
3. Hornblende-schist, with or without garnets.
4. Biotite-gneiss or schist, with or without garnets.
5. Graphitic gneiss.
6. Pyroxenite.
7. Finely laminated rocks with some resemblance to mylonites.

The rocks next the outcrops of marble vary in character in different places. On the N.W. side of Beinn Fhada the adjacent rock is sometimes pyroxene-gneiss; at Totaig sometimes garnet-amphibolite, or thin banded hornblendic gneiss, or pyritous schist with brown mica. Near Carr a garnetiferous biotite-gneiss or schist comes very near one side of most of the outcrops.

* *Summary of Progress* for 1898, p. 9.

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Many of the hornblende-schists are intimately connected with the eclogites, and form margins to them, or traverse them in thin bands, which seem to represent lines of shear. Others form parallel bands, sometimes hardly an inch thick, separated by bands of pale acid gneiss of nearly the same thickness. One hornblende-schist, on the E. side of Eilean Donnan, cuts the first foliation of an acid biotite-gneiss, and is perhaps of the same age as the "Scourie dykes" of Sutherland. Mr. C. T. Clough.

Some of the biotite-gneisses or schists near Carr contain biotite (often of a brown colour) in great abundance, and might be mistaken for micaceous "Moine-schists." They are, however, veined with many pale grey acid streaks, resembling foliated pegmatites. These streaks are more abundant than the pegmatites in the neighbouring "Moine-schists," and differ from them in being for the most part finely granulitic. Hornblende-schists are also sometimes interbanded with the biotite-gneisses, though it is not certain that they ever occur in the neighbouring Moine series.

The garnets in the garnetiferous varieties of biotite-gneiss are very abundant, and sometimes measure an inch across. Closely associated with these gneisses there are areas—sometimes as much as 3,000 square yards in extent—in which the rock chiefly consists of garnet and quartz. Crystals of kyanite, or lumps of small green micaceous scales—corresponding, perhaps, to the "shimmer aggregate" of Mr. Barrow*—which seem to replace kyanite, frequently occur, both in the garnetiferous biotite-gneiss and in the peculiar rocks just described. In one locality there are exposures, several square yards in extent, which consist almost entirely of garnet and kyanite, or of garnet and the green micaceous scales, in nearly equal proportions.

The graphitic gneisses† are usually pyritous, and so deeply weathered that it is difficult to procure good specimens. It is clear, however, that many contain diopside or some allied mineral. About 130 yards S.S.E. of the S.W. end of Lochan an Beinne Faide,‡ a seam unusually rich in graphite, and perhaps averaging 8 or 9 inches thick, can be traced for about 30 yards. Another good locality for graphite occurs 730 yards W.N.W. of the S.W. end of the same loch. The graphite here is very irregularly distributed, and occasionally occurs in masses an inch or two in length and breadth, which seem mainly composed of much crumpled scales, some of which are more than an inch long.

Intrusive dykes, striking W.N.W. and N.W., are abundant on the S.W. side of Loch Duich, but rather rare on the N.E. side. Some are composed of mica-trap, some of hornblende-biotite-

* *Quart. Journ. Geol. Soc.*, vol. xlix. (1893), p. 340.

† Graphite has also been noticed within siliceous lumps in marble, and in eclogite.

‡ This seam was pointed out by Mr. Murdo Murchison, the gamekeeper at Tigh Dhruideig. The name of the loch referred to is taken from the Ordnance Maps, but Mr. Murchison states that it is incorrect.

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Mr. C. T. Clough.

porphyrite, and some of felsite. A few dykes, with a nearly E.—W. direction, have a dark basaltic aspect, but some of them contain large flakes of biotite, and, perhaps, belong to the lamprophyre group.

Turning now to the region on the south side of Loch Hourn, where he has recently been at work, Mr. Clough remarks that most of the rocks in that district, so far as yet examined by him, belong to the type which was named by the Geological Survey the "Moine schists," none seeming to be referable to the Lewisian gneiss. A tract of at least nine or ten square miles is composed of a group of foliated rocks, most of the members of which contain a great proportion of mica, both biotite and muscovite. This group may provisionally be called the Ladhar Bheinn group, while the other more siliceous rocks, on either side of Ladhar Bheinn, may be classed together as the Beinn na Caillich group.

The Ladhar Bheinn micaceous schist or gneiss contains crowds of small garnets, usually the size of small shot, and small patches of garnet-sand are common in the alluvia. In the micaceous beds needles of tourmaline are here and there abundant, as on the coast 150 yards S.E. of Eilean a' Mhuineil, where some of them an inch long are bent and broken. Mixed with the micaceous portions there are in some localities bands of granulitic siliceous schist, which contain few or no garnets, and which seem even more siliceous than most of the Beinn na Caillich group. Numerous thinner garnetiferous siliceous bands, rarely more than four or five inches thick, contain conspicuous needles of hornblende, lying at various angles, and frequently across the foliation; also zoisite [9113].* These bands with hornblende and zoisite, are rudely parallel to one another, and sometimes also to other bands. This arrangement seems to indicate bedding, and probably the rocks represent altered sediments. The bands project conspicuously from many of the weathered rock-faces, and frequently show contortions which otherwise might escape notice. On the limbs of some of the folds they become attenuated, and sometimes altogether disappear. MR. TEALL states that they are allied to the zoisite-amphibolites noticed in Ross-shire by MR. GUNN,† but that some of them are more siliceous than the Ross-shire types.

After making allowance for folding, it still seems probable that the Ladhar Bheinn group was originally very thick. At the head of Coire Dhorcail its members form crags more than 1,000 feet high.

The Beinn na Caillich group is no doubt a continuation of the siliceous schists which on the N. side of Loch Hourn make up a large part of Ben Scriol. Both biotite and muscovite commonly occur in the rocks, but in small quantity compared to the granulitic material. Bedding is often indicated by variations in the proportions of mica, and in some places also by thin dark

* Figures in square brackets refer to the microscopic slides in the series of Scottish rocks in the collection of the Geological Survey.

† *Summary of Progress* for 1897, p. 41.

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streaks, generally less than an inch thick, which are rich in grains of ilmenite [9119]. In addition to irregularities in the bedding which appear to have been caused by deformation during contortion, there are others which may be due to original false-bedding. In many places the laminæ composing the apparently false-bedded bands seem to have been arranged in curves before the bands themselves were folded.* In some parts of the group, grains, both of quartz and felspar, probably represent clastic grains. Although to a considerable extent granulitized, they project somewhat on weathered faces, and can also be distinguished from the matrix by their freedom from micaceous scales. They are often in the form of short rods, with cross-sections less than $\frac{1}{8}$ inch in diameter. Sharply distinguishable from these grains, small spots of secondary felspar may be observed in some of the more micaceous beds of the group. They are generally quite free from granulitization. Mr. C. T. Clough.

The boundary between the Ladhar Bheinn and the Beinn na Caillich groups is not a sharp line. An intermediate zone, often from 50 to 100 yards wide, is composed of thin alternating bands, some siliceous and others more micaceous, many of them not more than an inch or two thick, but traceable for considerable distances.

It appears that at the present ground-surface the Ladhar Bheinn group is underlain on both sides by the siliceous schists of the Beinn na Caillich group, and the impression is given that the former are lying in a syncline of the latter, and are therefore of younger date. It is possible, however, that they lie in the central portion of a great fan-shaped fold, and that they were originally below the other group. On this view they would occupy somewhat the same horizon as other micaceous beds, which on the north side of Loch Hourn frequently occur between the Lewisian gneiss series and the siliceous Moine schists. On Ladhar Bheinn, however, the micaceous beds must be much thicker than any yet seen on the north side of Loch Hourn.

A mile or more west of the Ladhar Bheinn mass there is a broad band of schist, most of which differs from the common types found either in the Ladhar Bheinn or the Beinn na Caillich groups. A great part of this band is finely bedded, and contains many thin micaceous schists, which are crowded with small spots, the size of shot or small peas, of secondary micropoikilitic felspar. These spots closely resemble certain others already mentioned, which occur not far from the passage zone between the Beinn na Caillich and Ladhar Bheinn groups, and, as the beds on either side of the band are siliceous schists of much the same character, it seems possible that the band is due to repetition by folding, partly of beds near the passage zone and partly of Ladhar Bheinn beds. But none of the peculiar thin beds

* It has long been noticed that in many unaltered Torridonian grits and other sediments, the minor laminæ are often sharply curved, even when the bands which they compose are nearly horizontal. See Sir A. Geikie's *Textbook of Geology*, 3rd edit., fig. 197

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Mr. C. T. Clough.

with hornblende and zoisite have yet been noticed in it. The band is exposed on the coast between Ceum Garbh and Rudha Ruadh, and has been traced S.W. to Gleann Ghuserein. Its width is frequently about half a mile, but the boundaries are somewhat indefinite. The portions which most resemble Ladhar Bheinn schists increase in a S.W. direction, and are exposed over large areas on the N. side of Gleann Ghuserein, near the Priest's Pool.

In the district S. and S.E. of Barrisdale on Loch Hourn numerous pegmatites may be noticed, some of which are as much as thirty yards wide. Many are of very acid composition, and contain much quartz, as well as large plates of white mica, while others present brown mica and plagioclase felspar. Besides the broad pegmatites, many of which behave like dykes and cut the foliation and bedding, thin streaks and lenticles of pegmatite may be observed, which usually keep along the foliation-planes, and, in some places, occur in such numbers that, though rarely more than half an inch across, they form about half the rock and convert it into an "injection gneiss" or "vein-gneiss" ("adergneiss" of Sederholm.*) The thin, sill-like pegmatites are not necessarily accompanied by the dyke-like pegmatites, nor are the latter by the former. The sill-like seams are often disposed in sharp folds, and foliated across their sides in directions parallel to the axial planes of the folds, but the dyke-like bands often cut straight through folded beds and folded quartz veins. One or two dyke-like bands have been noticed to cut others of the sill type, though they seem to be of much the same composition.

In the part of the district displaying many pegmatites a few thin bands of granite-gneiss may also be seen, which cut the bedding. In the Ladhar Bheinn group on the coast between Eilean a' Mhuineil and Inbhir Dhorcail, in close association with the bands which contain hornblende and zoisite, a few thin beds of hornblende schist, none more than a foot thick, may possibly represent intrusive sills, but none has been noticed to transgress the bedding. There are a few thicker hornblendic bands, of variable composition, which are only occasionally foliated. With one doubtful exception all these lie E. of a line drawn N. and S. through Ladhar Bheinn. Like the hornblende intrusions in the Moine rocks on the N. side of Loch Hourn,† they generally cut the bedding-planes, and occasionally at right angles. Some of them are crowded with quartz-veins, as much as a foot or two broad, the marginal portions of which are frequently penetrated by long crystals of albite or oligoclase [9109 and 9110].

The intrusive masses which are never foliated may be divided into three groups. 1. Mica-traps and lamprophyres: in dykes

* "Über eine Archaische Sediment Formation im südwestlichen Finland," p. 133.

† *Summary of Progress* for 1899, p. 16.

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with a nearly E.—W. direction. 2. Basic dykes of uncertain age. 3. Dykes and sheets of Tertiary age. Mr. C. T. Clough.

The intrusions of the first group are somewhat rare in all parts. The dykes of the third group are very common in the W. part of the area, but rare further E. They strike N.N.W., and are composed of basalt and dolerite, or more rarely, of a rock allied to trachyte.

The dykes of the second group have only been noticed in the E. part of the area. On first inspection they appear like some Tertiary dykes, but they generally strike nearly E. and W., and contain small oval reddish or pale grey patches, often a quarter or half an inch long, in which occur small crystals of hornblende. Some—possibly all—of these patches have an amygdule near the centre. It seems probable, on the whole, that they belong to the lamprophyre group, but some are in a very fresh condition for such rocks. MR. TEALL states that they contain, in addition to the hornblende, more or less idiomorphic augite, together with occasional biotite and pseudomorphs after olivine [9111 and 9112].

The district in which MR. LIONEL W. HINXMAN has been mainly at work during the past year stretches southwards from Strathconon across Glen Strath Farrar to Strath Glass, and is entirely occupied by crystalline schists of the Central Highland type with their associated igneous intrusions. The lithological characters of these rocks and the general structure of the ground were fully discussed in the *Summary of Progress* for 1899, and the work of last year has revealed few facts of importance to add to that description. Mr. L. Hinxman.

The system of folding in Strathconon is of a more complex type than that which obtained in Glen Strath Farrar, and rapid changes in the pitch and direction of the long axes of the folds give rise to greater irregularity in the outcrops and areas occupied by the different zones in the former region. An important structural line of disturbance crosses the N.W. corner of the ground, and has evidently determined the N.E. course of the river Meig between Milton and Inbhir Chorainn. It is accompanied by a sudden deflection of the strike and a considerable amount of crushing along the eastern bank of the river. It is evidently a continuation of the line of fault or lateral wrench mapped by MR. PEACH in the ground to the north, and described by him in the *Summary of Progress* for 1898.

A small belt of rocks, distinctly separable in character from the muscovite-biotite-gneiss with which they occur, is exposed in the stream and at the foot of a crag near the road at Balnuilt in Strathconon. These fine-grained granulitic gneisses have a regular banded appearance, contain a large amount of epidote, and though generally acid, include several thin hornblendic bands. They appear to be separated from the overlying muscovite-biotite-gneiss by a line of movement and crush, along which the rock is very finely granulitic and even platy in structure. They strongly resemble in character certain gneisses of presumably Lewisian age further to the west.

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Mr. L. Hinxman.

A much larger outcrop of banded granitic and granulitic biotite- and hornblendic gneiss crosses the upper part of Glen Strath Farrar, one mile west of Broulin Lodge. The rocks are well exposed in the Allt Toll a' Mhuic, and from the lower part of the precipitous eastern face of Sgùrr na Muice, where they appear to dip beneath the flaggy siliceous "Moine schists." The further limits of this band have still to be traced, but it is known to extend westwards up the valley to the Uisge Misgeach, and probably forms part of the large mass of Lewisian gneiss mapped to the north of the river Meig and Loch Beannachan by MR. PEACH.

With regard to the igneous rocks of this district, it may be observed that sills of garnetiferous amphibolite are largely developed about Scatwell in Strathconon, where they are associated with the highly siliceous members of the "Moine schist" series. They die out rapidly to the westward, and higher up the valley are represented by small isolated lenticular masses. Some of these are full of very large garnets, and of amorphous lumps of garnet mixed with quartz and other minerals, and surrounded with a deep black mica—probably Haughtonite.

A small outlier of the Glen Orrin granite has been mapped on Meall Mòr, 1½ miles W. of the main mass. The intervening ground is full of small intrusions of granite and pegmatite, but beyond the immediate neighbourhood of these masses there is a striking absence of acid igneous material in the rocks between Glen Orrin and Strathconon. Several sills of mica-trap are found in the Moine schists of Strathconon, Glen Orrin, and Strath Glass. They have a uniform E. and W. trend; and though rarely exceeding two or three yards in breadth, often form conspicuous green features along the hill-sides.

Several mineral-veins are found in the Moine schists on the western side of Strath Glass between Struy and Crelevan.* They occur as veins of calcite containing abundant galena, zinc-blende, and barytes; and are associated with lines of fault-breccia that run nearly E. and W. approximately at right angles to the strike of the schists. The mineral-veins do not appear to be more than 2 to 3 feet in thickness, and have an average dip of 60°.

The lead ore was at one time worked to a considerable extent, but owing to difficulty of carriage the mines have long been abandoned.

A thin vein of plumbago, also worked many years ago, occurs in the muscovite-biotite-gneiss of Glen Strath Farrar, between Loch a Mhuilinn and Loch Bunacharan.†

* Heddle states that "crystallised galena occurs in glen, two miles from Struy Bridge, in barytes."—*Mineralogy of Scotland*, p. 17.

† The occurrence of this mineral here has long been known. JAMESON mentions that "it occurs in imbedded masses and disseminated in gneiss in Glen Strath Farrar, in Inverness-shire." *Manual of Mineralogy* (1821), p. 118. In HEDDLE's work just cited, the following statement occurs as to the working of the graphite at this place:—"In 1818 five tons were extracted, which sold for £93 each; the cost of raising was £13 per ton. It is associated here with felspar, quartz, mica, and garnet. The rock near the old workings now shows only scales of graphite taking the place of mica."

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Veins of rose-quartz are met with in masses of garnet-amphibolite at one or two localities in Strathconon.

Torridonian.

Mr. Harker.

The only district in which rocks of recognisably Torridonian age were mapped last year was in the island of Scalpay, on the east side of Skye, where the ground was mapped by MR. ALFRED HARKER. The Torridonian rocks cover the greater part of the island. The principal stratigraphical group represented by them corresponds with the Applecross group, and consists of coarse reddish felspathic sandstones, mostly pebbly, and often current-bedded. The lower division consists of finer-textured sandstones, often flaggy, felspathic in the upper part but quartzose in the lower. The normal dip is N.W. at about 20°; but there are local disturbances of Tertiary date, especially a broken synclinal, forming Mullach na Càrn, the highest ground in the island. The Cambrian limestones and quartzites are not found in Scalpay, and the relation of the Torridonian to the great post-Cambrian disturbances cannot be made out. It seems probable, however, that the rocks are overthrust, for on the Skye side of the Sound, only $\frac{3}{4}$ mile distant, the corresponding beds (the lower quartzose members) are seen resting upon Cambrian limestones.

Dalradian or Younger Schists of the Scottish Highlands.

ABERDEENSHIRE.

Mr. George Barrow.

MR. BARROW resumed in the early summer the mapping of the remote mountainous region at the head of Glen Tilt (which has an interest to geologists from the visit paid to it by HUTTON*), but, as already stated, was soon disabled by severe illness. He has supplied, however, some notes of the geology of the ground, based partly on previous examination. As shown in the stream-sections, the rocks have been intensely folded, the majority of the folds being of the isoclinal type, with limbs dipping at a high angle. A local peculiarity of these folds is that their crests are frequently seen just at the junction of two beds, so as to show which beds lie next each other. Thus the junction of the honestones and the quartzite is repeatedly exposed. The former are, moreover, at times so thin that they can be seen to lie between the limestone and the quartzite, and thus the order of three members of the succession can be determined. These honestones gradually pass into the dark schist so frequently associated with the limestone. The change in the material that lies between the limestone and the quartzite is occasionally remarkably sharp, while if the rocks are followed along the strike

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Theory of the Earth, vol. iii., p. 16.

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Mr. George Barrow.

of the folds it can often be seen to take place quite gradually. It should be remembered that the folds in the Highland rocks are of such depth that outcrops now close together were originally a considerable distance apart, so that the appearance of a sudden change may be entirely deceptive. The local variations in the bed next the limestone, where they can be followed along the strike, are not more rapid than those in the Yoredale rocks, and distinctly less rapid than those in the Lower Oolites of East Yorkshire. A dark schist, which is found on the side of the limestone furthest removed from the quartzite, can be identified from place to place by the fact that a well-banded rock composed of laminæ alternately poorer and richer in lime intervenes between it and the limestone, though where this rock is hidden by drift, it is not possible to say with which dark schist we are dealing.

Two intrusions of the older granite have been met with in this district. One occurs about a mile above Falar Lodge, and is cut through by the Falar Burn. Seen from a distance of about 100 yards, this rock presents the appearance of bedded sedimentary material dipping at a high angle. On closer inspection this appearance is seen to be due to the perfect foliation of the intrusion. The rock is now an augen-gneiss, composed of oval crystals of felspar wrapped round with dark mica. The larger felspars are either microcline or orthoclase, and the rock is identical with the Meall Gruaim augen-gneiss, from the lower end of Glen Tilt, described by MR. TEALL some years ago. Though this rock is so loose that much of it can be picked to pieces with the fingers, small cores can easily be met with from which sections can be cut, and these are seen under the microscope to be singularly fresh and unaltered.

The other example of these intrusions, which occurs near the Tilt valley, is the only case of the occurrence of this material not exactly along the line that intersects the belt of hornfels-alteration that has now been proved to extend for so great a distance, though it does not lie far off this line. It is less foliated on the whole than the augen-gneiss.

A number of thrust-planes have been detected around Falar. Now that the sequence of the rocks of the region is known, it may be inferred that the amount of displacement is usually small. The rocks intersected by these dislocations are highly schistose close to the face of the planes of movement, and have there acquired a thoroughly crystalline structure. The effects of the small thrust-planes are best shown by the quartzite. Owing to its hardness this rock has offered great resistance to crushing, consequently cores of white uncrushed quartzite are still seen in the mica schist. That the mica has been produced at the expense of the felspar material in the quartzite is well displayed, for distorted pebbles can be seen converted apparently entirely to white mica.

The fact of the occurrence of a number of minor thrusts leads to the suspicion that a major thrust-plane may exist in the district. The evidence seems fairly conclusive that a

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powerful thrust runs in the bed and along the west side of the upper Tilt. At the head of this long, singularly straight valley a striking contrast may be seen between the shapes of the two sides. The western shows a perfectly uniform slope, as if cut with a machine, at once suggesting the presence of a sole or surface of a thrust-plane. The other side of the valley is totally different in form, being sometimes precipitous, at other times presenting an easy slope. Indeed, the east side of the valley looks rather like an irregularly-shaped escarpment, with the sole outcropping from beneath. An examination of the rocks on the east side at the bottom of the valley shows that they become intensely schistose as they approach this sole. Mr. George Barrow.

These facts have been obscured by the much later Glen Tilt fault, which is essentially a normal one. It is accompanied by the usual angular shattering of the rocks, which has led to their decomposition, and has thus obscured their relations to each other. But for this circumstance, the presence of the proofs of some earlier movement, differing in its effects from a normal fault, would, no doubt, have been suspected long ago by some of the peculiarly able observers who have from time to time visited Glen Tilt. The normal fault is mainly older than the intrusion of the granite, as is shown by the abundant short dyke-like intrusions of that rock. But, as in the more northerly portion of its course, there have been post-granitic movements which have at times greatly crushed these intrusions.

It may be remarked in conclusion, that the stream-sections in the upper part of the Glen Tilt region have undergone a singular change since the members of the Geological Survey first examined them. They were remarkably clear and accessible when some years ago they were visited by Mr. Dakyns and Mr. Barrow. For a number of winters before that time the snow had melted in such a way as to slide down the steep sides of the gorges in great masses, tearing up any small trees that had begun to grow, and often taking with it the soil also. The banks of the gorges were thus mostly bare rock. For some unexplained reason this has not happened for at least ten years. On reaching Falar Lodge last June, Mr. Barrow was greatly astonished to see the sides of the stream densely wooded with small birch trees, which, as they have grown up, have arrested the downwash on the sides of the ravines, thus affording soil for the growth of grass. The Falar Burn in its lower part was from this cause quite unrecognisable. Many of the sections are now quite obscured, of which, fortunately, drawings and photographs were formerly taken.

While engaged for a short time in the early part of the summer tracing the limits of the basic portion of the Cairngorm granite between Glen Gairn and Crathie on Deeside, and in joining up lines with Messrs. Barrow and Cunningham Craig on the N. side of the Dee, Mr. Hinxman found that the separation of the basic modification of the granite from the typical acid granitite is attended with considerable difficulty, owing both to the gradual passage of the one rock into the other, and to the Mr. Hinxman.

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Mr. Hinxman.

drift-covered nature of much of the ground. In some localities and especially at Balfentaig and near Rechrachrie in Glen Gairn, the line between the flesh-coloured granitite and the dark quartz-mica-diorite with sphene is more or less sharply defined. Elsewhere there is an insensible gradation from the acid into the more basic rock, and specimens taken from various parts of the same mass will show an ever-varying amount of basicity. On the hill slope above the upper part of the Crathie Burn, and N.N.W. of Bridgend of Bush, the rock varies within a small area from a fine-grained diorite, chiefly composed of hornblende, to a coarse quartz-biotite-diorite or hornblende-granite, rich in potash felspar in the form of large crystals of pink orthoclase. Both acid and basic rocks are traversed by small later intrusions of a fine-grained grey rock with porphyritic felspar phenocrysts, belonging to the lamprophyre group.

Some interesting phenomena of thermo-metamorphism were observed in this region. The main mass of Culardoch, a conspicuous hill which rises on the S. side of the Gairn to a height of nearly 3,000 feet, is made up of highly altered sedimentary rocks. Garnetiferous mica-schists are found at the northern end; while the summit and steep southern face are covered with angular blocks of dark, ferruginous andalusite-hornfels sometimes containing tourmaline. It is evident that we are here dealing with altered phyllites and black schists of the Banffshire series, while there can be little doubt that this metamorphism is due to the Cairngorm granite which, in its more basic form, almost entirely surrounds the hill and crosses its S.E. shoulder in close proximity to the hornfels.

Intense contact-metamorphism was also observed in the Knoch of Lawrie, in connection with apophyses of the newer granite. Limestone bands have been converted into green calc-silicates, while the accompanying black schists pass into cordierite-hornfels, in which the characteristic puckering of these schists can still be detected.*

In connection with these observations on the Aberdeenshire ground, reference may here be most conveniently made to the results of a re-examination of part of the district of Strathspey by Mr. Hinxman together with Mr. Grant Wilson. Further study of the igneous masses of Hunt Hill and Netherly on the Burn of Rothes tends to prove that there is here a basic modification of the ordinary acid granitite, similar to that met with in connection with many other intrusions of the newer granite. The basic rock is a coarse-grained quartz-mica-diorite, the biotite often occurring in very large individuals. The granitite is of the usual Cairngorm type, and forms a complex with the surrounding sedimentary rocks, which are much impregnated with granitic material. The relations of these two types are nowhere clearly

* Mr. Cunningham Craig's account of the contact-metamorphism of this region and his description of recent work among the Cairngorm granites are given at pp. 19 *et seq.*

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visible on Hunt Hill, but along the roadside between Dandaleith and Craigellachie Bridge an apparent passage can be traced from a basic rock resembling the Netherly diorite into the red granite of the Rock of Craigellachie. Mr. Hinxman.

The district of Aberdeenshire surveyed last year by MR. CUNNINGHAM CRAIG, lies north of the River Dee, between Crathie and the Feardar Burn. It is chiefly remarkable for the number and variety of its igneous intrusions, the relations of these intrusions to each other, and their metamorphic effects upon the surrounding and included rocks of sedimentary origin. Mr. Cunningham Craig.

More than five-sixths of the ground, where free from drift, is occupied by igneous rocks, nearly all of which are holocrystalline, and all of which can be assigned with certainty to the age of the newer granites and diorites. The district lies just outside the area of the larger granitic tracts, being situated directly between the granite mass of Lochnagar and that of the eastern extension of the Cairngorm Mountains. The intrusions are for the most part comparatively small, and have been introduced at slightly different epochs in the period of igneous intrusion; it is evident that introduction of igneous material has taken place from a differentiating magma, and while no clear evidence of differentiation *in situ* has been obtained, many minor phases of the magma are represented.

The igneous rocks may be classified primarily into (1) Diorites and their apophyses, and (2) Granites and their apophyses. The various masses are very irregular in form at the surface, but often spread out into sheets, or sill-like forms, such as are so characteristic of the newer granites in the Braemar district.

The diorites are the earliest intrusions in this district. They vary in composition from a fairly basic diorite containing augite to a rock containing rather more biotite than hornblende, and which may even contain quartz, thus merging into the granitic type. All these plutonic rocks may have their fine-grained apophyses, as dykes or marginal belts, which range from camptonites to quartz-porphyrites.

Into and through these intermediate rocks biotite-granites, which also vary perceptibly in composition, have been intruded, and these more acid phases of the magma have occasionally, though much more rarely than the diorites, their fine-grained apophyses, eurites, aplites, and quartz-porphyries. Where a considerable mass of granite comes in contact with the dioritic rocks, the latter are frequently seen to have been fused or partially fused, so that an intermingling of the materials of the two rocks has taken place. This intermingling may have been assisted by chemical action. Specimens showing the incipient intermingling may be obtained in many localities, but more frequently the interfusion has been more complete, and a new rock, partaking of the nature of both granite and diorite, has been formed. As these mixtures of igneous material may have taken place between any variety of diorite and any variety of granite, it is evident that many rocks to which it is difficult to assign a name may occur. The belts

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Mr. Cunningham Craig.

of composite rocks of this nature never attain any great breadth on the surface, but are usually well defined, and have been mapped wherever this was possible, and distinguished from the diorites and granites. Some varieties have been mapped as tonalite; but the term is not often applicable, the usual type being a quartz-plagioclase-biotite-hornblende rock, often with large crystals of pink orthoclase---a hornblende-granite.

In many cases, where the conditions were not favourable, though the evidence is often insufficient to enable a cause for this to be determined, no interaction has taken place between the diorites and granites. In these cases the granitic intrusions are usually small; it is possible that the "quantity of heat" available was insufficient to fuse the earlier rock. Certain fine-grained intrusions may represent the dyke phases of the composite rocks, such as a quartz-porphyry with hornblende phenocrysts on Creag an Ordaigh. The hornblendes may, however, have been derived from the diorite through which the quartz-porphyry has been intruded.

Besides the larger irregular intrusions, dykes and veins are numerous in this area, especially those of acid material from the granite. In some localities, in a felspathic biotite-gneiss, the granitic veins become so frequent that the rock may be said to be permeated with igneous material, the crystalline constituents of which often "dovetail" with the crystalline constituents of the metamorphosed rock, giving an indistinct or welded junction. The material of these veins varies from a fine white aplite to a fairly coarse granitic pegmatite, while a faint pseudofoliation may be observed occasionally. Where the diorites are cut by the same veins the junction lines are sharp, and no trace of parallel structure in the veins is noticed. The areas where permeation has been observed can be traced with occasional gaps and intervals, where one of the larger intrusions occupies the surface or where the ground is drift-covered, for several miles to the westward and south-westward to Creag a' Chleirich, north of Braemar, where the permeation by granitic material beneath the sill of Auchindryne granite has been previously noted. (*Summary of Progress*, 1898, p. 32.)

With regard to the metamorphic effect of the igneous intrusions, the evidence is here strikingly complete. The area is one of slowly-cooled plutonic masses, quickly-cooled dykes being the exception; and so largely do igneous rocks occupy the surface of the ground that no exposure of original sedimentary rock has been observed at a distance greater than a hundred yards from one of the larger igneous masses. This is the measurement in a horizontal direction; measured vertically, the distance can usually be proved to be very much less, as the patches of metamorphic rock lie frequently above the intrusions, or, preserving their natural strike, are wedged between separate intrusions, *e.g.*, of granite and diorite. Lines of inclusions of metamorphic rock, maintaining a regular strike, can be traced in this manner along the hill sides. As might be expected under such circumstances every rock, which from its composition

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is susceptible of thermo-metamorphic change, is profoundly altered. Mr. Cunningham Craig.

Mr. Barrow (*Summary of Progress* for 1899) has called attention to the exceptional extension of cordierite-hornfels in this area outside the great granitic masses of Lochnagar and the Cairngorm Mountains. The aluminous black schist, wherever it appears in this area, is changed into hornfels, either as cordierite, andalusite, or kyanite-hornfels, often with a great development of contact biotite, all schistosity being obliterated, while the somewhat aluminous quartz-biotite-rocks appear as rusty banded gneisses or hornfels, containing sillimanite. Even the pure quartzite is greatly affected, presenting on a fresh fracture a coarse mosaic of glassy clear quartz, in which occasional felspar blebs may be detected. The bedding, except where colour-banding occurs, has been obliterated.

The metamorphism of the limestone, however, is perhaps the most striking test of the extent to which thermo-metamorphic processes have proceeded. The late Dr. Heddle has made the limestones of Creag Mhor, Creag Bheag, Creag an Ordaigh, with their magnificent development of silicates, well known; masses of garnet, idocrase, malacolite, wollastonite, etc., are the rule rather than the exception in the less pure bands, while those bands too pure to give rise to silicates are converted into a white marble, in which the individual crystals are sometimes as large as peas.

A remarkable case of interaction between an igneous and a sedimentary rock, or of the absorption of the latter by the former, has been observed on Creag Bheag, a mile north-north-west of Inver, where the diorite comes in contact with a considerable mass of limestone. For a distance of fifty yards the margin of the igneous rock is modified in a peculiar manner for a depth of not more than three or four yards. The section is not sufficiently well exposed to admit of all the evidence being made clear, but enough to establish the main fact has been obtained. The diorite inside this marginal zone is a normal fine-grained diorite, with some biotite, dark in colour, and showing no abnormal arrangement of the minerals. At the marginal belt, the character of the igneous mass changes rapidly but by perceptible gradations, the rock becoming an augite-diorite of a peculiar type. The material has a mottled appearance owing to the development of large ill-defined plagioclase crystals in a matrix composed of green lath-shaped crystals of diopside and felspar, with hornblende, quartz, and sphene in lesser quantity. The crystals of sphene sometimes attain a large size. Biotite is occasionally present near the passage into normal diorite.

Mr. Teall has examined specimens of this augite-diorite and has supplied notes on the microscopic features, from which the following remarks are taken:—

"[9124] Augite-diorite, composed of hornblende, diopside plagioclase, quartz, and sphene.'

"[9126] Variety of the above essentially composed of pale green pyroxene, plagioclase and sphene (in very large individuals). Apatite, rendered almost opaque by inclusions, is also present."

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Mr. Cunningham Craig.

It is to be remarked that this modification of the diorite is a purely local phenomenon; it appears that some part of the limestone has been absorbed, thus modifying the composition and totally changing the aspect of the igneous rock. A somewhat similar rock, for which a similar mode of origin has been suggested, has been described by MR. HINXMAN. (*Explanation of Sheet* 75, p. 27.)

Cairngorm Granite.—In the area of Cairngorm granite and contiguous flaggy biotite-gneisses surveyed last year in Sheet 64, the most interesting point is the occurrence of certain white muscovite-pegmatites in the metamorphic rocks. These pegmatites are confined to the area to the north-west of the great Clais na Fhearna fault, and with the exception of a few minute veins, all occur within a distance of a mile from the granite margin, but their petrological characters are so distinct from any intrusion recognisably connected with the granite mass, as to suggest a different origin. These pegmatites seldom attain a thickness of more than 4 feet, and can never be traced for any great distance; they usually follow the bedding of the country-rock in horizontal lenticles, though vertical veins are not infrequent. All exhibit a more or less distinct foliation and flaser-structure, which are more marked in the horizontal veins. The rocks consist of drawn-out lenticles of quartz and felspar, with plates and well-developed crystals of muscovite, surrounded by a granulitic matrix of quartz and felspar. Garnets are frequently present. Many parts of the veins are completely granulitised, especially towards the margins. In those veins which follow more or less closely the bedding-planes of the surrounding rocks, the foliation of the igneous material coincides with that of the metamorphic rock, while in the vertical veins the foliation frequently makes a large angle with the margins of the vein. From this relation it is evident that the foliation is not a protoclastic structure induced by flow during cooling, but has been developed by cataclastic action—a fact which suggests that these pegmatites are of earlier date than the granite. Evidence with regard to the Clais na Fhearna fault supports this view. Though all movement along this great line of disruption had not altogether ceased at the time of the intrusion of the Cairngorm granite, that mass of igneous rock is not very greatly affected, while the area in which these pegmatites occur in this district is bounded by the fault, as if they had been intruded prior to the dislocation. The state of metamorphism on the two sides of the fault does not differ greatly, though the country-rocks to the westward of the fault are obviously on a different horizon from those on the eastern side, as shown by the disappearance of solid quartzite bands.

MR. TEALL has examined microscopically two specimens from the foliated pegmatites, and calls attention to the absence of potash-felspar. The specimens consist of "grey granulitic biotite-gneiss" (the country-rock) "banded with white foliated muscovite-pegmatite, composed of large plates of muscovite, and sometimes large crystals of oligoclase, embedded in a fine-grained

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granulitic aggregate of quartz and oligoclase." The granulitization, foliation, and banding with the country-rock point to a common metamorphism. The behaviour of the muscovite, taken in connection with the absence of potash-felspar, confirms this view. The large muscovite plates and crystals are more conspicuous where the matrix is completely granulitised, or where there is evidence of the complete breaking down of crystalline groups of quartz and felspar. In some cases idiomorphic crystals of muscovite up to 2 inches in diameter have been developed across the foliation planes, and surrounded by the granulitic matrix. It is evident that such muscovites have not suffered from dynamo-metamorphism, they are probably secondary, and derived in great part from the destruction of potash-felspar broken down in the movement which preceded granulitisation. It may therefore be inferred that the pegmatites are older than the Cairngorm granite, and that a thermo-metamorphism has succeeded the shearing movement and affected alike the pegmatites and granulitic gneisses of the district. Mr. Cunningham Craig.

In the *Summary of Progress* for 1898 it was mentioned that the Clais na Fhearna fault—which is the great fault of Glen Tilt, Loch Tay, and Glen Ample—affects the Cairngorm granite in Glen Lui. It is not suggested that the intrusion of the granite was prior to the great faulting movement, but that some movement along this line of dislocation has certainly taken place since the intrusion. A small area at the head of Glen Gairn, surveyed this year, has yielded additional evidence of the fact that part of the movement has affected the granite mass. A precipitous gash, one thousand feet deep, which separates Creag na Dala Bige from Creag na Dala Mhor, marks the position of this line of disruption. Creag na Dala Mhor, the north-western side of the fault feature, is a spur of the granite massif of the Cairngorm mountains. At the mouth of this great natural trench, where it opens out into Glen Gairn, small exposures of granite are observed on the south-eastern side of the fault, and these show some signs of the crushing and veining common to the metamorphic rocks of the neighbourhood.

In the granite mountains to the westward, also, zones of minor crush-veins may sometimes be traced for miles, usually making well-marked features. As an instance, a zone containing many well-defined veins of this nature passes from the western flank of Beinn Bhrotain, north-eastward through Glen Geusachan, west of the Devil's Point, through Glen Dee, and breaks into many minor zones about the summit of Beinn Macdhui.

No single crush-vein can be traced for any great distance, but the zone in which these veins have been developed is well-defined. Such zones run parallel to the Clais na Fhearna fault, and probably represent minor movements of approximately the same age and type.

PERTHSHIRE.

With a view to obtain more light on the structure of the central Highlands, the band of schists known to the surveyors

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Mr. Cunningham Craig.

as the "Green beds" has been picked out and traced across the region. This revision was carried last year by MR. CUNNINGHAM CRAIG over the ground on either side of the Tay below Aberfeldy. It has helped to clear up some points in the tectonic arrangement of the rocks, and has thrown fresh light upon their metamorphism. The outcrop of these green beds was followed from Pitlochry southwestward to Dull, where it descends to the alluvium of the Tay valley. Folded outliers and inliers as well as repetitions of the bands due to faults across the strike of the folds, afford evidence of great value in elucidating the structure. This ground lies to the southeastward of the great central axis of folding of the Perthshire and Aberdeenshire Highlands, so that only a part of one side of the "fächer" or fan-structure is represented, the overfolds being towards the south-east or south-southeast. The flexuring, though sharp, cannot be described as isoclinal in the strictest sense, since the different limbs of the folds can usually be distinguished by their angle of dip. Nor are the folds of any great "amplitude," *i.e.*, the limbs of the folds are nowhere very long. The result is, that though the folding is not on a large enough scale to cause repetitions of the whole outcrop of "Green beds," where unaided by faulting, individual beds are repeated, and the outcrop is thus considerably broadened.

Another remarkable characteristic of the folds is that they are unsymmetrical, and consist of a longer limb the dip of which as a rule varies only a few degrees on either side of the horizontal, and a shorter limb inclined at a higher angle towards the north-west.

It is the development of the gently-inclined or larger limbs which gives to the area north of the Tay in which the "Green beds" occur the appearance of a flat step-feature lying to the south of the higher and more rugged line of hills formed of rocks higher in the succession, where the axes of the folds are more highly inclined. The same flat structure in the more uneven ground south of Aberfeldy gives a more complicated outcrop of the "Green beds." There are complications in the structure in this southern area which will be described more fully when the ground has been completely mapped.

Dynamic metamorphism in the stretching and shearing of material has had greater effect in the longer limbs of the folds than in the shorter limbs. It seems that this is due to the position of the longer, flat-lying limbs being more favourable to movement under lateral thrust. Subsequent or contemporary thermo-metamorphism has affected each bed differently, according to the different stages of dynamic metamorphism; the more a bed has suffered from the latter, the more susceptible it becomes to change under the former. In consequence, it is found that a bed where it is exposed in the longer limb of a fold, presents a different aspect from that where it is exposed in the shorter limb. These considerations are insisted upon, because their effect is to enhance the difficulty in many localities of distinguishing between "Green beds" and epidiorites in the field.

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The "Green beds" in the area north of the Tay are represented by fine hornblendic schists, usually containing small wine-coloured garnets. The foliation is well marked throughout, and is occasionally emphasised by the development of biotite on the planes of schistosity. The rocks have not the appearance of irregularly sheared material, the schistosity is constant throughout, and each bed breaks more readily along joint-planes than along the foliation-planes. Quartz is sometimes observed to be present, but no traces of original gritty structures are to be seen. The appearance upon a fresh cross-fracture is that of a mesh of minute hornblende crystals orientated in the planes of foliation. Microscopic examination, except of crushed and powdered material, has not yet been made. Mr. Cunningham Craig.

In many localities, confusion is liable to arise between the epidiorites and the "Green beds" of this area. As a rule, the epidiorites are readily distinguishable by their coarse crystals and "eyes" of hornblende, and characteristic mode of weathering; but where only the margin of a sill or only the longer limb of a fold is exposed, the rock occurs as a fine, well-foliated, hornblende-schist, which closely approaches the "Green beds" in appearance. This is more particularly the case in small sills of fine-grained epidiorites, such as are to be seen both to the north and south of the main epidiorite outcrop, but many of these may be merely repetitions by folding of the margin of a larger sill. It is where faulting and folding have reduplicated such sills and brought them into the same line of strike with the "Green beds," in an area in great part concealed by drift, that the greatest difficulty of distinguishing these rocks is experienced.

The difficulty has been overcome by observation of the following characteristics. The epidiorites have a less regular foliation than the "Green beds," frequently showing zones of alternately more and less schistose aspect, while on a cross-fracture much drawn-out "eyes" of hornblende are occasionally seen. On a fresh cross-fracture the epidiorite sills usually show a greater lustre than the "Green beds," while, when crushed for microscopic examination, it is seen that the hornblende is of a darker colour than that of the originally sedimentary rock. Biotite occurs less frequently and more sporadically than in the "Green beds;" quartz has not been observed; carbonates, possibly derived by secondary change from saussuritised felspar, are sometimes present, while garnets are very seldom seen. The characters of the associated rocks and the fact that the epidiorites occupy a higher horizon in the succession, have also proved of assistance in the distinction of these sills from the "Green Beds."

A sufficient area south of the Tay has now been examined to prove that a considerable decrease in metamorphism takes place in that direction. The "Green beds" afford a good instance of this diminution, but the evidence from them is not more striking than that from the other rocks of the district. North of the Tay no traces of original pebbles in the rocks which were once grits have been observed, except in a few rare instances.

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Mr. Cunningham Craig.

In the area to the south original gritty structures begin to appear, and become more conspicuous as the beds are traced southward. At the same time, garnets are seen to decrease in size and number, and finally to disappear from many of the beds. When the ground has been more fully surveyed this decrease in metamorphism will be described in greater detail.

During the mapping of the "Green beds," all necessary revision in the localities examined was undertaken. In the course of this revision another interesting example of an acid igneous rock intruded before the shearing and granulitisation, has been disclosed. This rock is exposed on the ridge dividing the valleys of the Tay and Tummel, about two miles S.S.E. of Pitlochry. Its outcrop is irregular, but attains a length of upwards of half a mile, and can be traced as far as the drift and fluvio-glacial gravels of the Tummel valley. It appears to have the form of an irregular sill, intruded more or less along the bedding-planes of the surrounding rocks. Introduced subsequently to the folding, this igneous mass has suffered from the shearing movement which appears to have been in this locality the latest phase of the dynamic metamorphism. The Director-General, who visited this locality in October, pointed out that on the crests of folds the foliation due to this later shearing movement could be distinguished from the early foliation produced during the folding. In the limbs of the folds these foliations coincide. The foliation is seen to pass from the surrounding schists, into and through the igneous rock, proving that it is a cataclastic structure.

The main mass of this intrusion consists of a granulitic muscovite gneiss, composed of a fine-grained granulitic aggregate of felspar (not determined) and quartz, with flakes of muscovite (probably in great part of secondary origin), orientated in the planes of foliation. Microscopic examination of the rock has not yet been made. Nests and veins of more coarsely crystalline material are frequent, and, especially near the margins of the mass, sometimes attain the dimensions of regular pegmatite veins. In these the crystallisation is very irregular and confused, and the foliation is by no means so apparant, being sometimes indistinguishable. Small quartz-veins occur here and there in the main mass of the intrusion. Pegmatite veins are numerous just outside the main mass; small crystals of tourmaline have sometimes been observed in them. A few small veins of a similar nature, seldom exceeding a foot in thickness, have been noticed at wide intervals to a distance of two and a-half miles to the westward and south-westward.

The effects of any metamorphism due to this igneous intrusion cannot be distinguished. It is evident that, as in the case of the Glen Dee pegmatites described above, both the igneous and the surrounding metamorphic rocks have been metamorphosed since the intrusion. In this case, however, granulitisation has proceeded further, for all traces of broken crystals or flaser structures have been obliterated. The rocks of the district have all developed garnets during thermo-metamorphism, which

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seem rather to decrease in number and size as the igneous rock and its pegmatites are approached. The garnets have crystallised since all shearing movement ceased, and are consequently of later age than the intrusion. Mr. Cunningham Craig.

Dumbartonshire and Stirlingshire.

The mapping of the Aberfoyle slate-bands in the neighbourhood of Garelochhead has been completed by Mr. Cunningham Craig, and an examination of certain other portions of Sheet 38 of the one-inch map has been made. A series of specimens for microscopic examination, collected from rocks on the western shore of Loch Lomond, from Luss to Ardlui, has likewise been taken as nearly as possible from the same horizon in the Beinn Ledi grits, between the Aberfoyle slates and the "Green beds." This series has been examined microscopically by Mr. Teall, who finds that the rocks show a well-defined progressive metamorphism from a slightly schistose grit or arkose near Luss to a highly crystalline albite-gneiss near Ardlui. The increase of both dynamo- and thermo-metamorphism can be distinguished, and will be described in detail in the Sheet Memoir.

The existence of "Green beds" near Ardlui has also been established by field-evidence and microscopic examination. These rocks have here attained a very much higher state of alteration than those on the same horizon in other parts of the district embraced in Sheet 38; they are represented by dark green hornblende-schists, containing occasionally "kernels," consisting of chlorite surrounded by clear zones of quartz and albite. Intercalated bands of what were once gritty laminæ containing less of the green material, exist as quartz-epidote schist, with hornblende and felspar, or as albite gneiss with some chlorite and hornblende.

A small mass of plutonic igneous rock north of Inversnaid has been examined. It proves to be a hyperite, consisting of large porphyritic crystals of augite and hypersthene in a holocrystalline matrix composed of bladed plagioclase crystals, hornblende, augite, and biotite, with iron-ores as accessories, and occasionally interstitial micropegmatite.

Inverness-shire.

With the exception of certain small patches near Daviot, the area surveyed by Mr. Horne during 1900, forms a belt extending from Farr and Tordarroch in Strath Nairn, eastwards by Ben Nan Cailleach and the Black Water to the neighbourhood of Tomatin. Within this area, the crystalline schists belong to two well-defined groups: (1) Muscovite-biotite gneiss; (2) Granulitic quartzose gneiss and flaggy quartz-biotite granulites. The members of the former group are typically developed in Upper Strathnairn, where they give rise to rough craggy hills between Farr House and Wester Lairgs, on the east side of the Nairn; and between Tordarroch and Loch Duntelchaig on the west. The dominant type is a coarsely-banded flaky gneiss, in which large plates of biotite and muscovite appear, together with Mr. Horne.

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Mr. Horne.

parallel folia of quartz and felspar. This type is usually garnetiferous and often highly corrugated. Small veins and knots of muscovite-pegmatite frequently occur. Again, the quartzo-felspathic folia and pegmatites sometimes disappear, and the rock merges into a flaggy biotite-schist. Lenticles of garnetiferous amphibolite are an occasional feature of this group. A traverse from Tordarroch in the valley of the Nairn west to Loch Duntelchaig furnishes good opportunities for studying the characters of this gneiss.

The boundary between the muscovite biotite-gneiss (1) and the quartzose flaggy gneiss (2) is well defined along the eastern margin, on the hills between Farr and Wester Lairgs, where it forms a highly sinuous line. The two groups have been affected by a system of inosculating folds, so that long tongues of the one appear in the other. Similar evidence of reduplication by folding is found on the west side, on the hills north-east of Loch Duntelchaig, where a narrow strip of quartzose flagstones intervenes between the margin of the Old Red Sandstone and the muscovite-biotite-gneiss. Eastwards towards Tomatin, the characters of the quartzose biotite-granulites are remarkably uniform. On Ben Nan Cailleach, however, near the watershed between the Nairn and the Findhorn, they become highly quartzose, and weather with a creamy white tint, presenting there the appearance of granulitic quartz-schists.

The southern portion of the Moy granite mass has not yet been mapped, and the description of the small area on the west side, surveyed during 1900, is meanwhile postponed. But close to the granite boundary, and within a distance of two miles from it dykes of microgranite, porphyrite and lamprophyre have been traced, which are probably the apophyses of that plutonic mass.

Mr. Grant Wilson.

Mr. J. S. Grant Wilson continued last year his mapping of the ground to the north of Ben Nevis. Reference has been made in former *Summaries of Progress* to certain dark-grey flaggy mica-schists, and silvery-grey phyllites, and garnetiferous mica-schists displayed in the gorge of the River Spean.* These rocks have now been mapped south-westwards up to the edge of the Ben Nevis granite. As they approach the granite, they gradually pass into dark-grey biotite-schists, and near the contact with the igneous mass become biotite-hornfels rocks. This aureole of progressive metamorphism varies from a quarter of a mile to a mile and a half in breadth. The schists are traversed by a large number of dykes, the rocks composing which vary in type from plutonic through hypabyssal to volcanic rocks. Several broad granite dykes may be noticed at the foot of the Corrie Rois. That the granite is the oldest intrusion is shown by the fact that one of these dykes is intersected by a camptonite dyke with chilled edges, while to the south of the Sgor Pheanais both lamprophyre and porphyrite

* *Summary of Progress* for 1898, p. 45; and *Summary of Progress* for 1899, p. 41.

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dykes traverse the granite. In the valley to the south of Corriecoille several altered diorite dykes are cut by lamprophyres. The network of dykes in the schist off the Corrie Rois and Corrie Eoin presents three distinct types, the oldest of which is red and pinkish porphyrite. The dykes of this material are generally of considerable size, one measuring 45 feet in breadth. They have a general trend of N. 30-45 E., and have been traced in some cases for 2,500 yards. They have been determined by MR. TEALL to be hornblende-biotite-porphyrites. They vary from a medium to a coarse grain. Dykes of lamprophyre running more nearly E. and W., cut these porphyrites, and are not so broad as the latter. They are, in general, fine-grained and possess chilled edges. They may be classed as dioritic lamprophyres,* though, in many cases, they have been identified as camptonites. At Tomnafet, Corrie Rois, Lianachan, the valley of the Cour below Coirecoille and at An Gurean, both the porphyrites and lamprophyres are traversed by grey-black hornblende-andesite dykes, similar to the hornblende-andesite rocks described by MR. TEALL† from the summit of Ben Nevis. Mr. Grant Wilson.

The line bounding the Ben Nevis granite has been mapped from the River Lundy to the top of the Aonach an Nid. It is remarkably irregular, the granite sending numerous long apophyses into the surrounding biotite-schist, and including numerous fragments of schist, which decrease in number and size with distance from the margin. A mass of granite, about one square mile in extent, not previously observed, has been mapped between the Coire an Rois and the falls of the Cour, at a distance of three-quarters of a mile to the east of the Ben Nevis "massif," and separated from it by a belt of biotite-schist. The mass is darker in colour than the rock of Ben Nevis and may be classed either as a hornblende-biotite-granite or a quartz-diorite.

Reference may be most conveniently made here to the resumption by MR. GRANT WILSON of the mapping done by him during 1899 on the Moor of Rannoch. Last year he extended the work to the south-west of the Tulla Water. His survey in conjunction with that by MR. KYNASTON on the west side of Loch Laidon has proved that the granite of Ben Cruachan is continuous with that of the Moor of Rannoch.

ARGYLLSHIRE.

The mapping of the Dalradian area, between Glen Orchy and Glen Shira, was continued by MR. KYNASTON from Dalmally, and the unfinished ground near the head of Glen Shira was completed from Inveraray. The remaining portion of the area to the north of Glen Shira was also completed from Dalmally before the close of field-work. The ground surveyed consists Mr. Kynaston.

* *Summary of Progress* for 1899, p. 41.

† British Petrography, p. 287.

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Mr. Kynaston.

entirely of rocks belonging to the calcareous-sericite division of the Dalradian schists, together with occasional small sills of hornblende-schist, and affords no fresh facts of any importance beyond those already described in former reports. (See *Summary of Progress* for 1899, p. 43.)

At Kilchrenan Mr. Kynaston was engaged in endeavouring to define the limits of the Loch Awe grits and quartzites. This was done as far as possible; but in many cases it was found quite impracticable to draw any hard-and-fast geological boundary line between these grits, more especially in their finer-grained portions, and the black slates, owing to repeated alternations and interfoldings of the two on a scale too small to be represented on the 6-inch maps. Opportunity was taken to re-examine the various members of the Loch Awe series of sediments and the principal igneous rocks of the district, both later and earlier than the foliation. The results of these observations as far as they concern the Dalradian schists will be here given.

The Boulder Bed.—An excellent exposure of this important stratigraphical horizon in the Dalradian series forms a crag-like feature capping a grass slope a mile and a half W.S.W. from Kilchrenan village. In the burn at the foot of the slope black slates are exposed, but the boulders in the boulder-bed appear to consist almost entirely of quartzite, and sometimes measure at least 2 feet in diameter. They are well rounded, as if water-worn, and comprise rocks of various textures; occasionally, also, a fragment of limestone may be observed. No igneous pebbles have recently been noticed here; but in 1898 Mr. Kynaston found a pebble, which on examination proved to be a fine-grained acid igneous rock, consisting almost entirely of granophyric quartz and felspar. The matrix of the bed consists in the lower portion of black slate, which shows in parts a well-marked banding or lamination, running obliquely to the cleavage. Towards the upper portion of the exposure this matrix becomes gradually quartzose. The presence in the bed of truly igneous pebbles, unlike any rock known in the immediate neighbourhood, indicates that this bed is not due to disruption *in situ*, but was a true conglomerate before any movement such as shearing or crushing took place. From another exposure of the boulder-bed a little farther to the north-east, in the same line of strike, Mr. Kynaston, in company with Mr. Hill, collected two or three pebbles of a rock strongly resembling a medium-grained grey granite. A similar boulder-bed, exposed on the shore of Loch Awe, just below the Free Church Manse, Kilchrenan, presents a quartzose matrix, and contains numerous fragments of limestone and black slate. Besides these, two or three small fragments of a pale greenish-grey porphyritic igneous rock were noticed.

A peculiar calcareous conglomerate, exposed 2 miles to the south of Portsonachan, and mapped some years ago by Mr. Hill, was re-examined. The matrix is schistose and highly calcareous, the planes of schistosity being vertical or nearly so. The pebbles are not abundant and are usually of small

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size, and appear to be restricted to a certain zone or zones. They consist of hard fine-grained quartzite, well rounded, and also some peculiar, elongated and flattened, whitish, felsite-like, fragments. Small fragments of pink felspar and grains of quartz may also be observed. A greenish highly vesicular rock occurs apparently as a thin band in this conglomerate, and a few fragments of a similar rock were also found surrounded by the calcareous matrix. It is probable that this band was folded in with the conglomerate and was fractured during the attendant movements, so that very possibly we have here a case analogous to the "crush-conglomerate" described by MR. HILL from near Inverliever, and possibly also on the same horizon. The quartzite and felsite-like pebbles, however, are undoubtedly original. In some respects the exposure has somewhat the appearance of a calcareous tuff. Mr. Kynaston.

Two of the quartzite boulders from the Boulder-Bed when examined in thin slices under the microscope [9059 and 9060] were found by MR. KYNASTON to consist mainly of quartz-grains, mostly well rounded, with a few turbid grains of both striped and unstriped felspar enclosed in a fine-grained usually quartzose matrix, sometimes exceedingly turbid, possibly from decomposed felspar. Some chlorite is also occasionally present. Small zircons are sometimes seen in the quartz grains [9059]. The quartz often shows strain-shadows, but there is scarcely any appearance of schistose structure in the matrix. On the other hand, the matrix of the boulder-bed itself is markedly foliated, and is sometimes seen [9060] to have been forced between the quartz-grains lying at the outer edge of a boulder, though as a rule the margin of each boulder is well defined under the microscope.

If an average quartzite-boulder be compared with the schistose grit, or quartz-schist, which is found close to and apparently above the boulder-bed to the S.W. of Kilchrenan, they will be observed to present on the whole a similar composition, but to show a marked difference in the structure. Whereas there is little, if any, schistosity in the boulders examined, the section of the "Loch Awe grit" [9061] shows much stronger strain-shadows in the quartz grains, a matrix of clear, finely-granulitic quartz, and partial granulitisation of some of the quartz grains, which act as "eyes" in the finer material, as it appears to sweep round them. The rock also contains two felspars, and what appear to represent small drawn-out fragments of black slate. It is not surprising that the harder boulders should have to a great extent escaped the effect of the dynamic forces. Under the influence of pressure they would naturally be more resisting than the softer matrix, which would tend to be squeezed round them. The boulder bed, in short, presents an "augen-structure" on a gigantic scale.

A porphyritic igneous pebble from the exposure of the boulder-bed on the shore below the Free Church Manse, Kilchrenan, shows [9058] phenocrysts of alkali-felspar in a pale brownish, finely-foliated matrix. The felspars are turbid from alteration, but often

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Mr. Kynaston.

have good outlines, and show Carlsbad twinning. They are often more or less tabular in form, and tend to lie diagonally with regard to the planes of foliation. Partially surrounding the phenocrysts is seen a finely granular mosaic, clearer than the rest of the ground mass, and this together with the felspar-crystal forms well-marked "eyes." Occasionally the felspars show cross-fracturing. Some ovoid patches of granular quartz are also seen, which may possibly represent original vesicles. The ground mass is strongly foliated, exceedingly fine-grained, and has a somewhat general fibrous appearance, owing apparently to the development of minute flakes of biotite along the foliation planes. The rock was evidently originally a felsite.

The granitic pebbles from the boulder bed, referred to above, are seen under the microscope to consist mainly of a somewhat coarse type of micropegmatite with some plagioclase, and some interstitial chloritic alteration products [9286].

The pale felsite-like fragments from the calcareous pebble-bed, 2 miles S. of Portsonachan, are seen under the microscope [905] to be schistose felsites, which, previously to their foliation, probably had a very compact and flinty texture. They show small felspar phenocrysts, which probably include orthoclase, in a finely-felsitic and somewhat banded matrix, which presents a few small quartz-grains, and is full of irregular opaque specks. Some bands show a finely granular quartz mosaic, and small colourless and pale green needles. The bands are divided by cracks, filled with an opaque material. Flow structure was probably originally present. It cannot be stated for certain that this pebble-bed is on the same horizon as the boulder bed at Kilchrenan. Anyhow, it is interesting to find igneous and foreign pebbles in both. The fragments of vesicular rock occurring in the calcareous conglomerate can scarcely be described as true pebbles, since they were probably derived, as above stated, from an adjacent band of similar rock, which must be classed with the epidiorites.

The following observations were made upon the so-called *Epidiorites* of the neighbourhood of Kilchrenan and Portsonachan. The examples examined may be divided into two fairly distinct classes, though it is probable that intermediate types also occur:—(1) The Dolerite or Diabase type, and (2) the Lavaform type. The former type is common in the area between the main-road, leading from Tayereggan to Glen Nant, and the Pass of Brander. It is also seen on the opposite side of Loch Awe at Bovuy, near Cladich. It occurs in large intrusive sill-like masses, and in a hand-specimen shows a coarse or medium-grained doleritic structure, the colour varying according to the proportion of ferro-magnesian constituents, and the nature and degree of the alteration which the rock has undergone.

A good example of this type occurs in a large mass situated three-quarters of a mile N.N.W. of Ballimore and within half a mile of the Pass of Brander. The rock is decidedly coarse, and shows clear felspars of elongated columnar habit, unorientated in a dark matrix. A similar rock, but finer grained, occurs a quarter of a mile N.E. of

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Ballimore. Under the microscope [9049, 9050] the plagioclase which is slightly cloudy, is seen to be frequently cracked and broken, accompanied by slight shifting on either side of the fracture as shown by faulting of the twin lamellæ. The interstices between the felspars are filled almost entirely with secondary minerals—greenish hornblende, chlorite, a pale greenish biotite, epidote, leucoxene, and carbonates. In one slide small patches of a clear mosaic may perhaps represent quartz [9050]. Apatite is accessory, and may occur in relatively large crystals with an elongated columnar habit [9049]. In the coarser and fresher specimen some original augite appears to be present [9049], though in a rather broken-up condition. This type of "epidiorite" was doubtless originally a plagioclase-augite rock closely allied to the dolerites and gabbros. One of the exposures of "epidiorite" examined (a quarter of a mile S.W. of Ballimore), shows large porphyritic felspars, measuring sometimes over 2 inches in length. Mr. Kynaston.

The "lavaform" type of "epidiorite" is well seen to the south of Portsonachan, near the central portion of a large mass with a breadth of about four miles, and again to the south-west of Kilchrenan. Two miles S.S.E. of Portsonachan a dark, almost black, schistose porphyritic rock presents under the microscope [9052] phenocrysts of plagioclase, rather turbid, often broken, and occasionally showing partial granulitisation. The phenocrysts have a strong tendency to a similar orientation. Some grains of green fibrous hornblende also occur, and amygdales of epidote, occasionally containing chlorite in addition. The ground-mass is well foliated, and appears to consist to a great extent of minute lath-shaped plagioclase, though it is a good deal obscured by secondary products, and by an opaque material in long streaks and strips, probably consisting to a great extent of disseminated iron-ore. There are also some larger grains of iron-ore, partially replaced by leucoxene. The rock has the appearance of a foliated andesite.

Not far from where this rock occurs, and associated with the same mass, a peculiar band looks at first sight as if composed of fragments of grit set in a greenish matrix. On closer examination, however, the apparently gritty portions are seen to consist of numerous lenticularly-shaped patches of a highly vesicular rock, the vesicles being filled with quartz, and standing out conspicuously from the surface of the mass. These lenticles appear to behave as "eyes" in a fine-grained greenish schistose matrix. A specimen from the vesicular portion was examined under the microscope [9053].

Numerous amygdales, occasionally measuring a quarter of an inch in diameter, but usually smaller, are seen imbedded in a brownish turbid matrix. The amygdales are sometimes almost spherical, though often more or less elongated in a similar direction, so as to appear oval or almond-shaped. They are filled with crystalline quartz, forming usually a rather fine-grained mosaic, which becomes coarser towards its central part. The coarser portions frequently show an undulose extinction

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Mr. Kynaston.

traversing several contiguous quartz grains, so as to give the appearance of an imperfect spherulitic structure. Some of the amygdales contain calcite in addition to quartz and occasionally some grains of epidote in their marginal portions. The ground-mass is too turbid to allow anything very definite to be made out of it. It seems to consist of felspar microlites in a dark, turbid, brown, undifferentiated (?) matrix; no phenocrysts are seen. The rock has strongly the appearance of a highly vesicular basic lava.

Another well-marked vesicular variety occurs as a band in the calcareous pebble-bed, already described, and also as fragments within it. A section from one of these fragments shows fairly numerous amygdales, filled with calcite, and mostly more or less drawn out. The main mass of the rock consists of larger and smaller lath-shaped plagioclases, unorientated, grains of iron ore, some greenish alteration-products, and interstitial matter. The structure is that of a very fine-grained dolerite or basalt, and probably the original composition had similar affinities. A somewhat similar rock, seen to the S.W. of Kilchrenan, forms hard, roughly spheroidal cores, packed closely together in a dull fine-grained green schist. The slide [9054] is crowded with epidote grains and granular aggregates. The rest of the rock is very turbid from alteration-products, but shows here and there numerous small felspar-laths and an occasional larger porphyritic felspar. The rock is well foliated.

We thus have varieties of the so-called "epidiorites," which in hand specimens and in thin slices under the microscope have every appearance of true lava. Save the lithological characters now described, however, no evidence has been observed in the field that any actual superficial outflows of lava occur among the Dalradian schists. On the contrary, the evidence, as is well known, has always hitherto tended in a contrary direction, and has shown, in most cases conclusively, that the "epidiorites" are really intrusive sill-like masses. Owing to the structural variations, however, which are frequently observable within the limits of a single mass, it may be that many of these constitute complex intrusions, due to successive in-fillings of material, or other causes, such as unequal cooling during movements in the mass; so that fine-grained lava-form types of rock might conceivably occur in the central part of a large mass, where one would otherwise expect to meet with coarsely-crystalline material. From the highly vesicular nature of many of these rocks it would seem not improbable that some of the intrusions did not come far short of the surface, if indeed they did not actually reach it. These lava-form epidiorites may be compared with the vesicular epidiorites reported by Mr. Symes from the Kilmelfort area,* and with similar rocks mapped last year by Mr. Hill in the Loch Awe area, near Inverliever.

* *Summary of Progress* for 1899, p. 62. Mr. Teall, in reference to Mr. Hill's rocks, has pointed out the resemblance between them and the lavas associated with Radiolarian cherts in the Southern Uplands of Scotland and other localities.

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Area between Glen Salach and the Head of Loch Creran, and Part of Glen Creran.—The mapping of this area is a continuation of the ground surveyed by MR. KYNASTON from Loch Etive side in 1896 and 1897. From the high ground, occupied by the Ben Cruachan granite, to the north-west of Loch Etive, the work was completed down to the shores of Loch Creran, and up to MR. SYMES' ground in Glen Salach. On the north side of Loch Creran and the lower part of Glen Creran the map was nigh carried up to the ground mapped by MR. GRANT WILSON in 1896. The area now to be reported on consists of quartzites and quartzose beds, phyllites, black schists, and limestones closely resembling those of the Loch Awe area. The more argillaceous and impure calcareous portions of the series have been converted into hornfels by the Cruachan granite. The exact limits of the hornfels area is naturally difficult to decide upon. Intense alteration into hornfels may be noticed at a distance of about a mile from the granite, this change gradually shading off into less altered rocks according as the distance from the granite increases. The alteration is distinctly perceptible along the shore of Loch Creran, near Creagan Ferry, 2½ miles from the granite. This is a continuation of the hornfels zone which has already been studied between Taynuilt and Loch Awe, and described in detail in former reports.* So far as observation has yet gone, no fresh points of petrological importance appear in the extension of the area. The results of field work in connection with the complex marginal area of the granite will be discussed more conveniently in the section dealing with the granites and other intrusive rocks. Mr. Kynaston.

Perhaps the most striking feature to be observed in the mapping of considerable portions of this area, is the extraordinary amount of repetition which similar lithological types present. Black or dark slaty schists and quartzose seams are alternately repeated in narrow zones or bands over several miles of ground, in a manner that would completely baffle any attempt at separating the kinds of rock on the map. We have, in fact, a banded series, consisting of repeatedly alternating zones of siliceous and argillaceous material. The rock may be quartzose, banded with black schist or, again, black schist full of quartzose bands, or again, it may be impossible to decide whether the rock is a quartzose black schist or an argillaceous quartzose schist. A hand specimen frequently shows the banding in a very perfect manner; while in the field the bands vary from a few inches up to broader zones quite easy of representation on the maps. This banded series does not owe its essential characters to folding, but to original sedimentary alternations. The finer bands often show intense crumpling, and in one case where fairly coarse quartzose bands alternated with a fine dark schist, the process of the development of "crush-conglomerate" structure was well seen. The rock had undergone shearing along planes running obliquely to the

* *Summary of Progress* for 1897, pp. 88–90; for 1898, pp. 82–91.

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Mr. Kynaston.

banding, the result being a tendency for the harder band to be drawn out into separate lenticular portions. This banded series is also occasionally seen in the Loch Awe area in certain parts of the Pass of Brander, but it is not there developed over such large areas as near Loch Creran. It is especially well seen on Ben Bhreac, to the east of Glen Salach, and on the hills on the north side of Glen Dubh. The alteration into hornfels tends to accentuate the banding, the hard striped and banded hornfels of this area being exceedingly characteristic.

A well-marked zone of limestone, of the Loch Awe type occurs at the mouth of the River Creran on the north side of the loch, and has been followed for a distance of 2 miles. Above it and on its north-west side is a band of typical black slates, followed by a series of fine-grained quartz-schists and quartzites with their zones of black schist. To the east of the head of the loch the limestone is well exposed in Allt Buidhe, where it is associated with quartzite and black and banded schists changed into hornfels. It is here a highly crystalline bluish-grey or white marble, some portions of it being strongly banded and puckered. The purer bands are more coarsely crystalline, sometimes showing zones of small garnets, while the impure portions consist of dark and pale bands, sometimes greenish, of calc-silicate hornfels, and resemble the banded calcareous series of the Pass of Brander. Intrusions of "epidiorite" are common in certain portions of the area, but are never of large size, frequently, and more commonly, only a few feet in breadth. A decided dyke-like behaviour is sometimes noticeable.

Blackmount.—The Dalradian schists, mapped by MR. KYNASTON from Kingshouse, on the western border of the Moor of Rannoch, are evidently an extension of the similar series (quartzose schists and quartzites), already mapped in Glen Orchy and the south-eastern part of the Blackmount on the one hand, and in Glen Etive on the other hand. In the Kingshouse district, owing to the extensive development of igneous rocks, only insignificant areas of sedimentary material have been mapped. The River Ba, above Ba Bridge, shows a good section of flaggy quartzose schists and quartzites. The rocks usually present different shades of grey, sometimes banded, and sometimes pink, owing to the presence of a considerable proportion of felspar, as is well seen in Allt Coire-an-Easain, a tributary of the Ba, and at Altnafeadh, near the head of Glen Coe. Micaceous schists, sometimes with two micas, are also seen in Allt Coire-an-Easain and above Ba Cottage. Garnetiferous mica-schists, such as these of Glen Etive and the more southern part of the Blackmount, have not so far been observed. Certain breccias in the quartzites will be referred to further on in connection with the volcanic rocks.

Igneous rocks later than the foliation of the schists.—During the early spring of last year, while mapping the Dalradian schists in the neighbourhood of Dalmally, MR. KYNASTON took opportunity of re-examining the remarkable eruptive mass of Glen Orchy. Although these rocks have in former reports been referred to as olivine-monzonites, reasons have been shown in

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the paper referred to below for discarding the term in favour of a new one, and the term Kentallenite has been proposed, the rock from Kentallen,* near Ballachulish, being taken as the type. A detailed examination of the section exposed in Allt Broighleachan showed the lowest portion of the mass to consist of a band of coarse *hornblende-picrite*. At its lower margin the picrite passes into a marginal modification resembling a basic lamprophyre. At the upper margin it passes somewhat abruptly into the kentallenite in such a way that no sharp line of demarcation can be traced, nor any well-marked transitional phase. The lower portions of the kentallenite are, however, more basic than the normal type, showing very little felspar, with a high proportion of augite and olivine, and a very coarse texture. Followed upwards, in the burn-section, this type passes into the normal rock, which again shades into a less basic and slightly finer-grained variety towards the upper margin of the mass. On the whole, then, the variation is well marked and of a vertical character. The upper portions of the intrusion, as in the Carboniferous picrite of Blackburn, Linlithgowshire, are the more acid, while the more basic minerals have tended to concentrate in the lower part, and have consolidated as a layer of ultra-basic rock. Mr. Kynaston.

Under the microscope the picrite is seen [9009] to consist essentially of olivine, hornblende, augite, and biotite. Only a very minute and insignificant quantity of felspar is occasionally to be seen interstitially. Magnetite is accessory, but chiefly occurs in connection with the alteration of the olivine. The olivine is fairly plentiful in rounded grains. The hornblende varies from brown to greenish, or is sometimes almost colourless, the various gradations of colour being often visible in the same individual; it occurs in large irregular poikilitic plates, which enclose both the olivine and augite. The pleochroism is not markedly strong. Occasionally this mineral seems to form a marginal outgrowth from the augite, and may perhaps be partially formed at its expense. The augite is colourless, or almost so, and seldom shows crystal form. The biotite is of a deep orange-brown variety, and strongly dichroic. It is of later formation than the hornblende. Felspar is rare, but occasionally occurs in small interstitial patches, without any signs of twinning. This is somewhat suggestive of orthoclase, since we know that the plagioclase of the closely associated kentallenite crystallised out before the biotite, and the orthoclase last of all interstitially. The order of consolidation of the minerals in the picrite is—olivine, augite, hornblende, biotite, felspar. Towards its lower margin the picrite becomes finer-grained and shows affinities to the basic lamprophyres, while vein-like streaks and patches rich in felspar are not uncommon. The microscope shows [9007, 9008] this marginal portion of the mass to be rich in hornblende,

* Described by Mr. Teall, *Ann. Rep. Geol. Survey*, for 1896, p. 22. *Summary of Progress* for 1899, p. 57. See also a paper by Mr. J. B. Hill and Mr. Kynaston, *Quart. Journ. Geol. Soc.*, vol. lvi., pp. 534, 535, etc., and pls. xxix., fig. 2., and xxx., fig. 1.

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Mr. Kynaston.

while the proportion of olivine and augite has considerably diminished. The hornblende is green and greenish brown, and occurs in idiomorphic prisms, frequently giving a lath-shaped section, as in camptonite. The augite is considerably altered and sometimes pseudomorphosed. The olivine is represented by pseudomorphs of colourless amphibole needles and magnetite. Secondary green hornblende-needles often form a border surrounding the pseudomorphs. Some biotite is present in small flakes, and sometimes small grains of sphene [9008]. Felspar is fairly plentiful, and resembles that of the lamprophyres, occurring as small plagioclase crystals with good idiomorphism. A small quantity of interstitial quartz is present. Patches rich in felspar are somewhat coarser than the surrounding rock, but graduate imperceptibly into it. They consist of idiomorphic plagioclase and micropegmatite.

Passing now to the upper part of the picrite mass we find, as we approach the kentallenite, that the rock becomes slightly coarser, and that the microscope shows [9010] the hornblende to have diminished, while the augite has increased, the hornblende usually occurring about the margins of the augites. The proportion of felspar does not appear to have perceptibly increased. The next phase in the mass that is exposed is a basic form of the kentallenite, showing a low proportion of the felspars, and occasionally a small quantity of pale green hornblende [9011]. In the typical kentallenite the hornblende has entirely disappeared, and the biotite is of a browner colour, and does not show the rich orange tinge characteristic of that mineral in the picrite. The upper margin of the kentallenite does not assume a particularly fine-grained aspect, but seems to show an approach to lamprophyre [9015]. It is too decomposed for satisfactory description. The variety, which shows well formed olivines and augites in a ground-mass of biotite, plagioclase and alkali-felspar, is not a marginal modification, but occurs as roughly spheroidal masses, up to 2 feet or more in diameter, enclosed within the normal type. In one place a narrow vein was seen of very coarse white felspar and large biotite plates, doubtless analogous to the pegmatite veins so common in certain granites, and consisting, as is also the case in pegmatite, of those constituents of the parent rock which were the last to crystallise out from the intruded magma. Some interesting inclusions were observed in the picrite. Ignoring occasional pieces of quartzite, they are of two kinds:—(1) mushroom-shaped inclusions, 6 inches or so in diameter, of fine-grained kentallenite, and (2) nodular lumps, a few inches in diameter, of a fine-grained dark greenish rock, resembling certain lamprophyres, and showing conspicuous phenocrysts of hornblende. The rock of the mushroom-shaped inclusions consists [9013] of relatively large, idiomorphic, zoned augite and olivine in a fine-grained ground-mass of felspar, with elongated, irregular, strips of biotite, and small pyroxene granules. It resembles the rock of the spheroidal masses in the kentallenite. The other inclusions consist of large

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brown and greenish hornblendes, resembling the hornblende of the picrite, in a micro-crystalline and rather peculiar ground mass. It is not uniform in composition; some parts, though rather obscured by decomposition, appear to consist of plagioclase and orthoclase with some scattered hornblende needles, while other parts are rich in alkali-felspar, and crowded with small colourless grains and crystals of pyroxene. Some sphene, apatite, and magnetite are also present. It is not easy to explain these inclusions; they may, perhaps, represent magmatic concretions or consolidations of an earlier phase. That they are intimately and genetically connected with the mass in which they are found, their petrological affinities sufficiently show. They afford, moreover, an interesting link completing the chain of evidence which binds together the picrites, kentallenites and lamprophyres. Mr. Kynaston.

It may further be stated in this connection that while working in Glen Shira in September, Mr. Kynaston revisited the kentallenite intrusions, mapped by Mr. Hill, of the Brannie and Allt-ant-Sithein burns. That of the Brannie burn, like the Glen Orchy mass, was found to be associated with a coarse dark-greenish picrite, which occurs at the lower margin of the kentallenite in the burn-section, and apparently forms a band about 15 yards in breadth. There seems to be no great amount of variation in these Glen Shira kentallenites. What there is appears to be mainly textural, the rock becoming finer-grained at the margins, and finer and coarser varieties occasionally seem to alternate in successive bands.

The recognition of picrite in intimate association with the Argyllshire kentallenites is of special interest, inasmuch as it proves that ultra-basic rocks must be included as an additional group in the large and varied series of associated intrusive rocks, which form so marked a feature in the geological structure of the district.

Brief reference may here be made to certain sills of augite-diorite on Meall na Laoigh, between Glen Orchy and the head of Glen Strae, a specimen from one of which has already been described.* Fresh observations have brought out some interesting points bearing on the nature of the intrusions and the relationships of some of the rocks in the same area. They are composite sill-like intrusions, each exhibiting precisely similar features. At the margin, a fine-grained rock, resembling in hand-specimen a basalt, shows phenocrysts of augite and olivine. This passes into the main mass of the intrusion, an augite-diorite, consisting of idiomorphic augite, two felspars, and biotite, with an occasional accessory pseudomorph after olivine, and some sphene and magnetite [8945]. The central portion of each intrusion, however, is a rock of more acid appearance, consisting essentially of elongated prisms of greenish-brown hornblende and alkali-felspar, with accessory plagioclase. The alkali-felspar

* See *Summary of Progress* for 1899, p. 60; *Quart. Journ. Geol. Soc.*, vol. lvi., p. 546.

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Mr. Kynaston. consists of a granular aggregate, forming, as it were, a ground mass, in which the idiomorphic hornblendes lie embedded [8946]. A similar structure is seen in some of the Cornish minettes described by Collins,* in which the matrix that encloses the other constituents is a coarse-grained aggregate of unstriated felspar. The Meall an Laoigh rock may be classed as vosgesite, hornblende being the predominant ferro-magnesian mineral. Sphene and apatite are accessory. The boundary between this rock and the augite-diorite is sometimes, but not always, sharp. The vosgesite appears to be merely a slightly later intrusion from the same magma. It has no chilled edge, so cannot be regarded as a later dyke cutting the augite-diorite; but it is often rather intermingled with the latter rock, in irregular veins and strings, as if intruded before the diorite's complete consolidation. And further, the augite phenocrysts, so characteristic of the diorite, are also found sparingly, as hornblendic pseudomorphs, in the more acid rock.

The basic rock, forming the marginal portion of these sills, shows under the microscope [8944] phenocrysts of idiomorphic augite and pseudomorphs after olivine, in a microcrystalline ground-mass consisting of lath-shaped plagioclase, small greenish (?pyroxene) granules, the interstitial matter possibly including some alkali-felspar and accessory magnetite. The pseudomorphs after olivine illustrate the amphibole type of alteration. They consist of a fine felted aggregate of colourless amphibole-needles, sometimes associated with some iron-ore, and are usually surrounded by a border of green fibrous amphibole, often mixed with colourless needles.

A similar alteration-product after olivine is seen at the margin of the Glen Orchy picrite (see *ante* p. 37), and is probably similar to the "pilite" of Becke.† This marginal phase has affinities with certain basic lamprophyres and with the variety of kentallenite which occurs as inclusions in the picrite already described. This association of rock types observed in these Meall an Laoigh sills furnishes another example of the close genetic relationships between the augite-diorites and the lamprophyres of this area. In its general features the differentiation observable in these intrusions is closely paralleled by several of the intrusions of the Ben Bhuidhe area, and especially by the dioritic intrusion of Clachan Hill, which varies from augite-diorite, occasionally showing accessory olivine-grains, and in part closely resembling a basic lamprophyre, to a dioritic rock of the camptonite type.‡

Mr. J. B. Hill. The field-work carried on by MR. HILL in the summer lay in the district around Kilmartin, to the south-west of the Loch Awe basin. The whole of the members of the "Loch Awe

* See Teall, British Petrography, pp. 355-357.

† See Teall British Petrography, p. 86, and Rosenbusch and Iddings, Microscopic Physiography, p. 217 and pl. xix., fig. 2.

‡ These kentallenites and augite-diorites are most probably of the same geological age as the Ben Cruachan granite, in view of the close relationships that have been shown to exist between them.

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series" are here developed, consisting of grits, slates, and lime- Mr. J. B. Hill.
stones, with which are associated enormous masses of igneous material of Dalradian age, ranging in composition from intermediate to basic, while porphyrite dykes of later date are met with, probably belonging to the period of the Lower Old Red Sandstone. Further a series of Tertiary dykes of basaltic type traverses the county in a north-westerly direction at right angles, to the strike both of the sedimentary groups and of the igneous rocks associated with them.

The "Loch Awe series" having been described in previous Reports calls for no further description here. The limestone forms its base, and the grits and quartzites are its upper members. The different groups of the series often shade laterally into one another. The limestone especially is often most variable in character. From its normal condition of a crystalline blue limestone it passes to a calcareous grit on the one hand and a calcareous slate on the other. In its gritty condition, which is very common in this area, the limestone matrix is full of grains of blue quartz and felspar, sometimes an inch in diameter.

The rocks are everywhere thrown into isoclinal folds, which are steep, often even vertical. The bedding is, on the whole, not far from the horizontal, with foliation nearly vertical. The members of the Loch Awe series lie here in a gentle trough of the Ardrishaig series. The metamorphism is of a feeble kind, some zones having practically escaped alteration.

The igneous rocks of epidiorite type are extraordinarily abundant. They can be traced as a belt five miles broad, amongst which discontinuous strips of sedimentary rocks are enclosed, while fringing this mass the igneous material so diminishes as to present the normal condition of large sills enclosed in the sedimentary formations. This remarkably extensive tract, although composed of material that may generally be described as epidiorite, embraces rocks so little altered that their original igneous structures remain conspicuous. They vary in composition from basic to intermediate, the dominant minerals being hornblende and felspar, with chlorite, epidote, calcite, quartz, and iron ores as accessories. Every gradation in structure may be followed from a coarse gabbro-like type to the finest schist. The most prevalent variety is a felspar-hornblende-schist, with porphyritic felspars scattered in it, commonly associated with bands of very fine chlorite-schist, in which the porphyritic felspars are equally abundant. Rapid alternations occur of zones, in which the porphyritic felspar varies in amount, and is sometimes altogether absent. Similarly the ground-mass varies both in texture and composition. These differences in structure and composition, being often sharply marked off from each other, produce banded structures in the rock, while some of the chloritic bands in which porphyritic felspar is absent cannot readily be distinguished from sedimentary material. The porphyritic felspars occur in idiomorphic crystals, but they are often broken across and have rounded outlines; yet, not-

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Mr. J. B. Hill. withstanding the highly sheared condition of the matrix, they have on the whole suffered but little crushing. They are frequently half an inch long, while occasionally crystals 2 inches in size have been observed. In some zones the porphyritic felspars are so packed together that the ground-mass is almost excluded. Although some portions of the mass show the hornblende as porphyritic, this type is not common, the felspar being usually the porphyritic constituent. While as a whole the rock is fairly fresh, considerable masses present a highly decomposed condition in which the hornblende is entirely broken down, though tiny felspars often remain. In this state the rock often becomes strongly calcareous from the breaking down of the lime-bearing hornblende and felspar, and partly doubtless from the decomposition of the limestones with which they are associated. The green calcareous schists thus produced are often difficult to separate from rocks of similar character which are undoubtedly of sedimentary origin. Many of those rocks, both in the most and the least altered state, possess a vesicular structure, the vesicles being sometimes filled with calcite, more rarely with blue quartz, or remaining as partially-filled drusy cavities. Where the igneous mass is least altered the porphyritic felspars of idiomorphic character have suffered little or no alteration, hornblende is absent, and the structure of the rock is truly igneous, consisting of bands of more or less altered andesites divided by more sheared portions which may represent flow structure. Mr. Teall has pointed out the resemblance of these unaltered rocks to the volcanic accompaniments of the Lower Silurian Radiolarian cherts in the south of Scotland and elsewhere. They can be traced into normal epidiorites of Dalradian type, and, as already remarked with regard to examples in Mr. Kynaston's ground, the field-evidence usually favours their intrusive origin. No example has here been found of the peculiar sack-like or pillow-shaped structure, so characteristic of the lavas associated with the Radiolarian cherts. Nor has any trace been found of such cherts, or of volcanic tuffs or agglomerates. Epidote, is common to all the different types of the epidiorite, but the occasional occurrence of albite in tiny clusters, somewhat similar to those in the mica-schists of Cowal, is of interest.

The smaller sills that lie beyond the boundaries of the large mass need no special remark, as they present no characters which are not represented within that mass. In connection with the little-altered andesitic varieties, reference may here be made to rocks of similar type, which in 1893 were mapped by Mr. Hill, between Kilchrenan and the Pass of Brander, and of which the original igneous character is not much altered. In these rocks hornblende and chlorite, generally such conspicuous minerals in the epidiorite group, are absent, the ferro-magnesian minerals being represented by green biotite, while in one instance white mica also occurred. Mr. Hill's former work in the "Loch Awe series" proved that the normal crystalline schists of the Highlands pass gradually in this part of Argyllshire by phases of diminish-

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ing metamorphism into sedimentary strata little removed from normal Palæozoic formations. His recent observations show that in the same region these rocks include a large mass of truly igneous material which has undergone so little alteration that its original crystalline characters can readily be determined Mr. J. B. Hill.

The isoclinal type of plication, so prevalent over the district, has sometimes been developed to such an extent that the junction-line of two rocks is now marked by a banded zone, in which the alternations are so narrow that they range from a foot to as little as an inch in thickness. While in some cases the process has ended here, in others it has been carried further, and the sharply-packed folded bands have been divided by shear planes that sever the continuity of the limbs, the fragments thus produced having been more or less isolated, until at last, by the rolling out of these fragments, pseudo-conglomerates or crush-conglomerates have been developed. These structures have been observed in the limestone, the quartzites, and the epidiorites, but they are most conspicuously developed where the limestone and epidiorite are in juxtaposition. Sections are rarely seen in which the various stages of this process can be continuously traced from the beginning to the end. Consequently, structures which have originated in earth movements may sometimes be confounded with phases of contemporaneous deposit, such as the great boulder-bed of the Central Highlands already referred to.

As the principal topographical features of the region correspond both with the strike of the beds and the axes of folding, deep transverse sections showing clearly the passage of one rock into another are far from plentiful. The ground near the upper end of Loch Craignish, however, is divided by valleys which cross the lines of ridge. Isolated platforms have thus been blocked out, so to speak, from the rest of the country, and as these transverse valleys have had their trend determined by lines of fault, they display steep escarpments in which sections are laid open across the strike and the axes of plication. While the folding and foliation are everywhere seen to be dipping at high angles, the escarpment-faces show that the strata, although somewhat undulating, are on the whole practically horizontal, a structure exactly the reverse of what the surface-features would suggest. Examination shows that a mass of gritty limestone is overlain by an epidiorite sill, of which probably only the lower portions are to be seen. The visible part of this sill is of the vesicular type, and is probably an extension of the great sill already alluded to. The junction of the igneous sheet with the limestone is intricately folded, strips of epidiorite from a few inches to a foot or more in thickness being packed together at a high angle in a limestone matrix. Large blocks may be seen in process of division by the shearing movements which have succeeded the folding. Amongst the folded limbs boulder-like blocks occur completely isolated. These blocks are usually of epidiorite, but some of limestone may also be seen. The limestone, however, seems generally to have played the part of a plastic body, accommodating itself as a matrix to the folded and

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Mr. J. B. Hill. isolated fragments of epidiorite, between which it has been squeezed. A bed of this fragmentary nature, varying from two to six yards in thickness, rests on the limestone more or less horizontally. In this bed the long edges of the folded limbs and detached fragments are in alignment with the strike of the foliation and of the axes of the folding, so that a cross section displays a series of closely-packed lenticles standing on edge, bound together in a limestone matrix. The junction of this composite mass with the limestone below is not sharp; igneous blocks, some of which are well rounded, being included in the limestone for some distance, while near the junction of the limestone solid cores of epidiorite occur, two or three feet across, which have not been broken down into boulder-like masses. The blocks of epidiorite, a foot or less in length, are often perfectly rounded and lie in places at some distance from the nearest visible epidiorite. An examination of them shows that they belong to the vesicular type of epidiorite which reposes on the limestone, but many of them are fresher and more compact, with no trace of foliation. Blocks of the more decomposing type, which is the prevalent feature of the parent mass, do, however, occur. There seems on the whole to be ground for assuming that these "crush-conglomerates" are older than the foliation, and that the boulder-like blocks largely escaped deformation owing to the relative plasticity of the limestone in which they are interned. Boulders of grit may also be seen in the limestone, evidently derived from a grit band which is sometimes found to abut against that mass.

The district presents many examples of this peculiar structure at the junction of the epidiorites with limestone. But these phenomena are also observed amongst other rocks; they have been seen in the quartzites and within the epidiorites themselves, although in these latter cases, owing to the comparatively homogeneous nature of the material, they are not so conspicuous. Isolated blocks of quartzite have often been observed in a matrix of the same material, likewise boulders of slate and limestone have been met with enclosed in limestone. For want of a better explanation, they have been assumed to be related to the Highland boulder-bed, but there can be little doubt that in this part of Argyllshire they are more often crush-conglomerates.

The crush-conglomerates of Cornwall were described in the last *Summary of Progress*, and their relation to the composite nature of the beds in which they occur was pointed out. Bands of alternating material of different kinds offer a resistance to stress less uniform than that shown by more or less homogeneous masses. In Argyllshire crush-conglomerates have most frequently been formed near the junction of rocks totally dissimilar in character, the junction of epidiorite and limestone being especially favourable for their production. The limestone associated with these conglomerates is generally of a gritty nature, which may have favoured differential movements within its mass.

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Mr. Grant Wilson.

The mapping of that northern part of Argyllshire which forms the district of Ardgour, on the west side of the upper section of Linnhe Loch, was resumed last year by MR. GRANT WILSON. In this district a foliated epidiorite was encountered in the year 1898 at the foot of Glen Scaddle.* The field-work during the past season has shown that the area occupied by this igneous rock and its accompanying margin of acid gneiss is much larger than was at first anticipated, since it extends as far south as Sgùrr nah-Eanchainne, above Glen Gour. The hill-streams on both sides of Glen Scaddle afford clear and continuous rock-sections, and a large number of these have been examined. In the following table the various igneous rocks, which form the Glen Scaddle network, are arranged in their chronological order of intrusion, the oldest being placed at the beginning and the youngest at the end:—

Foliated Rocks.	(1) Epidiorite.	
	(2) Granulitic gneiss.	
	(3) Diorite dykes, cutting granulitic gneiss and flagstones.	
	(4) Grey basic dykes, now represented by Hornblende-biotite-schist	Cutting epidiorite, granulitic gneiss, and flagstones.
	(5) Granulitic gneiss and Aplite (porphyrite) dykes	Cutting epidiorite, granulitic gneiss, diorite dykes, flagstones, and grey basic dykes.
Unfoliated Rocks.	(6) Granite dykes	Cutting diorite dykes, epidiorite sills, and flagstones.
	(7) Dolerite dykes, Basalt dykes	Cutting all the other members of the series.

(1.) A microscopical description of the epidiorite has already been given,† together with a description of the section exposed along the course of the River Scaddle. The epidiorite continues to present the same general features as in the portion previously mapped, save that towards its centre the rock becomes less foliated, is much coarser, and contains hornblende crystals sometimes half an inch long. At many points not far from its margin the uniform grey colour of the rock changes to a dull red tint, owing to the pink hue of the felspar. As the ground is almost entirely free from superficial deposits, the outline of the epidiorite has been accurately traced for a distance of seven miles. It is remarkably sinuous, as the eruptive mass projects in tongues into the surrounding rocks.

(2.) Between Keil and Craigbheitheachain the epidiorite is surrounded by a zone of granulitic gneiss,‡ which varies in breadth from 10 yards to half-a-mile. The line of junction between the two rocks is everywhere sharp, contrasting in this respect with the line between this gneiss and the flagstones, which is indefinite, and much more complicated. For some distance beyond the zone of acid rock the flagstones are often traversed by numerous small dykes of acid granulitic gneiss.

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* *Summary of Progress* for 1898, p. 40. † *Ibid.* ‡ *Ibid.*, p. 41.

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Mr. Grant Wilson.

(3.) In Glen Cona the river-section for a distance of half-a mile below the Keeper's house, exposes numerous foliated diorite dykes from two to thirty feet broad which traverse the flagstones. Some of these in turn are cut by small dykes of granulitic gneiss and veins of aplite. To the south-east of Glen Scaddle several broad diorite dykes cut both the acid gneiss and the flagstones.

(4.) Eleven foliated grey basic dykes,* now represented by hornblende-biotite-schists, were mapped last year on the southern slopes of Glen Scaddle. They intersect both the epidiorite and the granulitic gneiss, while two in Glen Cona traverse the flagstones.

(5.) On the south side of Glen Scaddle the epidiorite is cut by a large number of dykes and veins of foliated granulitic gneiss and aplite (porphyrite)† from an inch up to twenty yards in breadth. Similar dykes have also been mapped to the south-east of Corrlarach in Glen Cona intersecting the flagstones.

(6.) On the east side of the Gearr Lechdann in Glen Cona a rocky ravine in the flagstones exposes dykes of foliated diorite which are cut by small dykes of unfoliated pink granite. On the top of the hill above the ravine a large diorite dyke, which extends for some distance, is also traversed by no less than three dykes of unfoliated granite.

(7.) No further remark is called for in regard to the basic dykes of probably Tertiary age.

The granulitic micaceous flagstones ("moine schists") in the ground surveyed last year on the north side of Glen Cona are of the usual type, and call for no special mention. They are traversed by sills of foliated epidiorite and dykes of pink unfoliated granite. On the hillside above Corrlarach, and also in the river to the south-east of it pegmatite veins occur, apparently an eastward extension of the large veins which traverse the flagstones to the north-west of Glen Cona.

Mr. R. G. Symes.

The tract of Dalradian rocks surveyed last year by Mr. R. G. Symes embraced the islands of Lunga, Luing, Torsay, and Shuna along the west coast of Argyllshire. The following account of the work has been drawn up by Mr. Peach, who supervised the progress of the mapping.

Lunga, the most westerly of these islands, as was long ago shown by MacCulloch, is almost entirely built up of massive quartzite and siliceous schists, presumably the northern extension of the Jura and Scarba rocks. Two outcrops of impure slate of no economic value occur on the east side of the island, near the solitary dwelling-house, where they are involved with the quartzite in the system of isoclinal folds into which the rocks of the whole island have been thrown. The long axes of the folds and the strike of the strata trend nearly north and south, while all the beds appear to dip at high angles towards the east. Trials have been made to work the slate, but without success.

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* *Summary of Progress* for 1898, p. 41. † *Ibid.*

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Luing, the largest of these islands, lies to the east of Lunga, and is only separated from the island of Seil on the north side by the narrow Cuan Sound. The rocks of Luing are, therefore, a continuation of those of Seil, and are arranged in the same system of isoclinal folds so well seen in the slate quarries of Easdale and elsewhere in Seil. The same slate and limestone bands also occur on different outcrops over an area of country more than two miles wide measured across the strike. The greater part of Luing is, therefore, built up of slates, phyllites, and limestone bands. Occasional bands of quartzite and siliceous schist occur in the middle of the island, and a massive sheet or sheets of epidiorite are folded with the limestone and phyllites towards the east of the island. This igneous intercalation is probably the continuation, through the island of Torsay, of the sheet which occupies the centre of a compound syncline on the south-east of Seil. If this be the case, then the structure of Lunga is also that of a compound syncline. In the north of the island the strike of the beds is nearly N.N.E. and S.S.W., but in the southern half nearly N. and S., while their general dip throughout is towards the east. Mr. R. G. Symes.

The equivalents of the rocks of Shuna on the mainland appear to be a portion of the Ardrishaig phyllite group, the Black slate group, and the Loch Awe limestone. The workable slates of this island as well as Seil probably belong to the Black slate or Black schist group.

Torsay and Torsay Beag are only periodically separate islands, for the channel between them and Lunga is laid bare at low water. The same rocks and structures that occur on the west of that island are continued through them. The larger of the two islets is made up chiefly of slates and phyllites that form the eastern limit of the compound syncline just referred to, while Torsay Beag, lying in the centre of the trough, is formed of portions of the great epidiorite sheet. Thin epidiorite sills, however, occur folded with the slates and phyllites on the eastern shore of Torsay. No slates have been worked on these islands.

Shuna lies to the east of Lunga, being separated from it by Shuna Sound, which is more than half a mile wide. Nearly all the western side of the island is composed of calc-sericite schist and impure limestone bands. From Shuna Point, its extreme southern headland, the western shore for some distance northwards is occupied by a band of massive quartzite, which at a point south of Shuna Cottage is truncated by an east-west fault, with a downthrow to the south. The remaining part of the island is made up of silvery grey phyllites and mica-schists. The strike of the beds is N. and S., and their dip persistently eastwards, which causes its calcareous sericites to seem to underlie the grey phyllites, but owing to isoclinal folding this appearance may be deceptive. Some of the impure limestones have been extensively burned; but at present a better limestone is imported from Lismore. The rocks of Shuna probably belong to the Ardrishaig phyllite series of the mainland.

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Mr. R. G. Symes.

In addition to the granite masses that occur in the neighbourhood of Kilmelfort,* numerous bosses of granite have recently been found on the mass of high ground to the south of Glenmore. The granite of these masses is similar in character to those already reported on, and the alteration round about them identical. The granite is fine-grained with prominent biotite, and, as MR. TEALL has ascertained, with augite as a constant constituent. Within the contact zone of this rock the ordinary phyllites are converted into biotite-hornfels, while in the impure calcareous rocks calc-silicates have been developed, and the rocks become calc-silicate-hornfels, in some cases pyroxene-epidote hornfels. Near its contact with the schist the granite passes insensibly into a rock with a felsitic ground-mass. From the mode of occurrence of the granite masses in the area south and west of Kilmelfort, there is reason to believe that they form part of one great intrusion which has lifted up the schists and altered them, and that the separate areas now exposed are due to unequal denudation. Further, the distribution of hornfels in places where there is no visible granite suggests that granite may be concealed beneath, so that all the granite bosses in the Kilmelfort may actually be connected below ground. In the *Summary* for 1899 it was suggested that these bosses had probably all been derived from the same magma. When the fact is considered that the granite edges and apophyses pass insensibly into porphyrites which sometimes exhibit flow structures, there is evidence in favour of the opinion that the granites may have been connected with the later and more acid phases of the Lorne volcanic episode (Lower Old Red Sandstone), and that the volcanic rocks of that region ascended from the same underground magma as the granites and porphyrites now referred to. If this view be eventually established, it will form another interesting addition to the examples of granite of Old Red Sandstone age, and to the association of granite with abundant volcanic manifestations.

Mr Peach and Mr. Wilkinson.

Island of Jura.—The survey of this island was finished last year. In order to ensure its completion, MR. PEACH took a portion of the ground on the west side of the extreme north end of the island, and he has furnished the following abstract of his mapping:—The same rocks which constitute the rest of the island to the south are continued to the northern extremity. They consist of partially granulitised quartzites and quartz-schists, which are sometimes pebbly and even conglomeratic, and phyllites, some of which merge into the quartz-schists on one side and into pure phyllites on the other. In places they are calcareous or dolomitic, and are traversed along the bedding-planes with worm casts identical in character with the so-called "Fucoids" found in beds on the shores of Islay and in the Cambrian rocks of the North-West Highlands. The general assemblage of these Jura rocks resembles in every respect that met with in Islay, from the basement quartzite up to and including part of the so-called "Fucoid-beds."

* *Summary of Progress* for 1899, p. 63

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Over the whole area mapped the rocks dip persistently towards the S.E. and E.S.E., at angles varying from 20° to 50°, so as to give rise to the deceptive appearance of an upward succession from west to east; but on close examination they are seen to be folded upon themselves in sharp isoclinal folds, the axes of which have a north-easterly and south-westerly trend. Several distinct lines of actual disruption or thrust planes with nearly the same inclination as the strata, are well exposed along the wave-swept coast, while small reversed faults may be observed in great numbers. The phenomenon of "staving" of the beds is also very conspicuous, especially among the overriding masses that have been pushed along the thrust planes. The band of "pipe rock," first observed by the Director-General on the shore of Glendebadel Bay,* was traced inland across a peninsula to Glengarrisdale Bay, where, in addition to the ordinary "pipes," trumpet-shaped pipes were found to occur in it. The "pipe-rock" band was also found and traced along several outcrops on various strikes. From the character of this band and its relations to the rest of the quartzite it cannot correspond to the "pipe-rock" zone found in Islay, but must be an integral portion of the basement quartzite. Mr. Peach and Mr. Wilkinson.

The fucoidal calcareous phyllites are best seen on the shore at Bagh Uamh nan Gall, near the cave at the eastern angle of the bay, and on the flat shore near the mouth of Allt Loch na Conaire, where the matted sandy worm-casts weather out on the surface of the schist in fine relief. This bed was also found on other outcrops further to the east. A calcareous band, in which no worm-casts were observed, occurs near the outcrop of "pipe-rock" in Glendebadel Bay, and probably supplies the calcareous matter for the stalactites found in a cave near its outcrop. A band of conglomerate occurs on the shore near the outcrop of this band of "pipe-rock" in Glengarrisdale Bay, the matrix of which is quartzite. It contains pebbles of granite like those in the quartzite conglomerates and the Port Arkaig conglomerate in Islay. This band probably corresponds to the conglomerate found in Islay near the top of the basement quartzite.

From these facts it may be inferred, with strong probability, that this part of Jura is built up of the basement quartzite, and the lower part of the "fucoid-beds" of Islay, spread out by constantly repeated isoclinal folds, thrust planes, and reversed faults.

On the east of the island at Barnhill and Kinnachdrach, and for about a mile north as far as Port an Draighann, schists with quartzose and calcareous beds and some few small beds of blue limestone have been mapped by MR. S. B. WILKINSON. These strata are similar to the group of schists met with further south at Ardmenish and Ardfin, and also in the island of Islay. Due east of Barnhill House the strata become conglomeratic; their matrix consists of highly calcareous material, enclosing pebbles and lenticular masses of

* *Summary of Progress* for 1898, p. 68.

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Mr. Peach and Mr. Wilkinson.

various rocks. These enclosures consist of blue, violet, and white quartz, limestone, felspar, grit, and possibly granite. Some of the lenticular blocks are a foot long. Underneath these fragmentary beds lie flaggy quartzose grits and highly-puckered black slates with small quartzite bands.

From the nature of the materials, the constant alternations of the beds, and the continuous easterly dip, the western and northern sides of the north end of Jura are remarkably bold, rising abruptly by a succession of cliffs to heights of from 600 to 1,100 feet within a mile or so of the shore. The hills and cliffs are further trenched by glens and steep-walled gashes, along which the streams make their way to the sea. Almost every one of these trenches, as well as the indentations on the western shore, corresponds to a weathered-out dyke of igneous rock or shattered fault-line.

The oldest of the intrusive igneous rocks are basic dykes now in the condition of epidiorites, many of which have been traced throughout the ground surveyed last year. For the most part they have a general N. and S. course, but constantly give off branches which may reunite with the parent dyke or cross obliquely from one dyke to another. One example was traced across the area at nearly right angles to the general trend. These epidiorite dykes occupy more or less vertical fissures which must have been formed after the corrugation and foliation of the quartzite. Their material is fine-grained, more or less foliated near the margin and coarser and unfoliated in the interior, but the felspars are now represented by saussuritic aggregates, and from their light glaucous green colour it may be inferred that they probably contain a considerable amount of chlorite. The foliation near their edges is evidently due to motion after consolidation.

This ancient system of dykes is cut by sills and dykes of unfoliated lamprophyre which may be seen on the shores and in the cliffs overhanging Glentrosdale Bay and Bàgh Uamh Mòhr, Beinn nan Capull. Both of these series of igneous rocks are in turn cut by dykes of olivine-basalt and dolerite, which occur in considerable numbers, and have a trend from E.N.E. to W.S.W. Two large dolerite dykes are traceable right across the island from shore to shore. The age of the epidiorites is unknown, though it must be later than the general plication and foliation of the quartzites and schists. The lamprophyres may be connected with the protrusion of the great granite masses on the opposite mainland, and may thus belong to the time of the Lower Old Red Sandstone, while the basalts and dolerites no doubt form part of the abundant records of Tertiary volcanic action in the West of Scotland.

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Silurian.

Wicklow and Wexford.

Mr. Egan and Mr. McHenry.

The revision of the Silurian tracts of Counties Wicklow and Wexford, which was resumed last year by Messrs. Egan and McHenry, was completed before the end of the working season. Mr. Egan's illness prevented him from continuing in the field after the beginning, and his subsequent death has deprived the Survey of the report which he would have furnished of the recent mapping. The following notes are condensed from the details supplied by Mr. McHenry.

The conclusions formed in previous years as to the nature of the so-called lavas and tuffs in this region were generally confirmed by the revision of the remaining portions of the ground last year. The rocks represented on the published maps as contemporaneous diorites, felstones, and ashes appear to be, at least in the great majority of cases, of truly intrusive character. In the case of the fragmentary masses the resemblance to agglomerate and ash is regarded as largely due to crushing by earth-movements, while the rocks lay deep below the surface of the earth. It is further believed that both the early basic masses and the later acid series were intruded amongst the sediments in the form of laccolites, sills, and dykes. As in many instances the felstones pass gradually into granites of the same type as that of the Leinster mountain range, it may be inferred that these rocks belong to the same system of intrusions as the Leinster granite, which is of the age of the Old Red Sandstone.

The intrusive sheets examined last year, wherein this passage is most apparent, lie to the south-east of Enniscorthy. The felstone of Vinegar Hill in that district is sometimes brecciated, and shades gradually southward into a granitic rock, which, on the published map, has been classed as "Elvan." Again, ten miles to the south-west of Enniscorthy, the hill two miles south-west of Chapel Rail Station shows a central portion of the laccolite to be granite, which merges outwards all round into a felsite. Still further south-west (Sheet 168) the acid mass of Carrickburne Hill passes from a central granitic core into a felspathic rock, which presents flow and spherulitic structures, as well as considerable brecciation. At Knockcarroll (Sheet 168) another example of the gradation from a granitic into a felsitic rock is to be seen. The felsitic masses show more or less deformation or brecciation* where the crushing is most evident. Innumerable included portions of indurated sedimentary materials, sometimes fossiliferous, have been caught up in them. These inclusions vary in size from masses half a mile long down to the smallest particles, the larger examples having generally a lenticular form, and being arranged parallel to the general strike and crush-line zones of the country. Many small dykes mapped as "elvans" occur in the vicinity of both the larger felsitic masses and the granite.

* *Summary of Progress* for 1899, p. 179.

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Mr. Egan and Mr. McHenry.

Brecciation has taken place to a considerable extent in the felsitic bands, notably in the Tara Hill mass, to the north-east of Gorey, and in the large knoll to the W.S.W. of Ballycanew (Sheet 149). It is displayed in many places in the Enniscorthy area, and further southwards (Sheets 168 and 169). Fine examples may be seen in Carrickburne Hill, where the broken-up felsitic fragments exhibit flow-lines, and are enveloped in a matrix showing spherulitic structure. Specimens of all these rock-varieties were collected, but have yet to be examined and reported on.

The revision of the Silurian areas in the counties of Wicklow and Wexford has thus shown that the rocks represented on the published maps as felstone-lavas are in large measure intrusive sheets, and that the so-called "greenstone-ash" consists of more basic dykes and sills, which have acquired a fissile or schistose structure owing to intense deformation. A revision of the mapping of the igneous rocks of this region would thus greatly reduce the number of rocks of truly volcanic origin. That such rocks, however, exist in the Silurian series of this part of Ireland appears to be sufficiently established. Thus, on the sea coast north of Courtown (Sheet 149), between Duffcarrick and Ballymoney Fishery, bedded tuffs are well exposed. The Director-General, after having visited the locality in two successive years, made the following notes on this coast-section:—

Director-General.

"In again traversing the Duffcarrick shore from south to north I was once more struck by the evidently intrusive character of the felsites at the south end of the section. These rocks are not uniform in texture, some parts being close-grained and flinty, others more granular-crystalline, while certain pale decomposing portions show a porphyritic structure. As they are traced northwards, an increasing number of fragments of black and grey shale are seen to have been caught up in them. These enclosures are generally arranged parallel with the planes of rude cleavage by which the felsites are traversed. Then come highly-inclined and disturbed lenticular bands of grey and black shale, much compressed and drawn out between the felsite intrusions, and succeeded thereafter by thick continuous bands of similar shales. The black shales have yielded graptolites which prove the strata to belong to the Llandeilo group. A little north of the first thick band of black shale there comes in a group of grey shales full of lenticular bands and lenticles of brown ferruginous limestone, belonging to the Bala group. The distance measured across the strike between the last visible exposure of the black shales and the first observable members of this calcareous series is 27 yards. This interval is obscured by the sand of the beach. At the most there cannot be more than 80 feet of strata between the representatives of the Llandeilo and Bala sub-divisions, but the relations of the two groups are unfortunately concealed.

"The bedding of the Bala group, owing no doubt to the greater diversity of the strata, is more distinct than that of the black shales. It can be seen to undulate towards the south-east at angles of 35 deg. and upwards. But the calcareous strata have

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been intensely cleaved, the planes of cleavage being nearly vertical and running in an E. and W. direction. Immediately beyond these strata, after a concealed space of a few feet by which the relations of the rocks are at present concealed under the accumulations of the beach, a remarkable brecciated conglomerate makes its appearance in distinct beds which dip gently towards N.E., that is away from the Bala Limestone. This fragmentary series of strata contains abundant fragments of limestone, and also rolled shells and corals from that rock, and pieces of Llandeilo black shale. It has been so intensely cleaved that the pebbles have often been turned round so as even to stand at right angles to the bedding. The matrix is a fine felsitic material which encloses numerous small lapilli of felsite and other igneous rocks. If this matrix has not been derived from volcanic discharges, it must at least have resulted from the degradation of volcanic rocks exposed to aqueous action. The conglomerate or breccia passes rapidly upward into fine grits with thin partings of shale, and is soon succeeded further north upon the shore by Llandeilo black shales and "ribboned slates," which are believed to belong to the Arenig division. Director-General.

"These conglomerates and grits are obviously younger than the Bala Limestone. They may form the base of some later member of the Silurian series, but no clue has yet been obtained as to their true age and stratigraphical position. Their intense cleavage shows that they must be more ancient than at least the later movements by which the older Palæozoic rocks of this region were affected. Not improbably they may eventually be shown to be of Llandovery age, marking, perhaps, the base of the Upper Silurian series in this part of Ireland. If it can be established that the matrix of some portions of the conglomerates and grits is of the nature of volcanic tuff, it would be an important addition to our knowledge of the history of volcanic action in this region.

"Further north a remarkably interesting section is exposed near Ballymoney Fishery. A coarse agglomerate rises there in a bold cliff along the inner margin of the beach. Along its southern border it presents a nearly vertical junction, probably a fault, against a mass of black Llandeilo shales. Entirely unstratified, it is crowded with large and small blocks of black shale and various felsitic rocks. Like the calcareous conglomerates and grits further south, it has been greatly cleaved, and the enclosed fragments tend to range themselves along the vertical or highly inclined planes of cleavage. This rock may mark an actual volcanic neck or orifice of eruption. If so, its origin must at least date back from an earlier time than that in which the cleavage of the rocks was completed. It appears to pass northward into a group of well-bedded breccias and fine grits, which have a south-westerly dip at angles varying from 15 deg. to 40 deg., and are made up of alternately coarser and finer detrital materials. Their highly felspathic composition suggests that they may have been largely derived from volcanic discharges. The cleavage which has affected them is similar to, though

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Director-General.

rather less strong than that of the adjacent rocks. In this section also it was impossible to trace the relations of these tuff-like strata to the surrounding Silurian rocks. At present the evidence strongly points to the existence here of true volcanic rocks; later probably than the Bala group, but older than the cleavage of the district. As the cleavage does not affect the Carboniferous Limestone of Wicklow and Dublin, we may infer that the volcanic episode occurred during some part of the long interval between the close of the Lower Silurian and the commencement of the Carboniferous period. The rocks do not resemble those of the Old Red Sandstone, but are not unlike some parts of the Upper Silurian formations. It may be added that nothing like these apparently volcanic strata of the coast has been detected anywhere in the interior of this part of Ireland."

Mr. McHenry and Mr. Seymour.

After the completion of the revision of Co. Wexford, and having joined up boundary-lines with Mr. Kilroe, working northwards from Waterford, Mr. McHenry was employed with Mr. Seymour in the re-examination of some portions of the ground north of Dublin, especially with the view of applying the knowledge acquired during the recent field-work in Wicklow and Wexford to the investigation of the rocks shown on the published map (Sheet 91) as felstone and diorite. The result of this re-examination has been to show that the so-called "felstones," and some of those classed as "diorites," are really composed of detrital materials (arkose). As these coarse fragmental strata always occur close to Lower Silurian fossiliferous rocks, they may not impossibly represent the basement beds of the Upper Silurian formation, especially as close to them fossiliferous Upper Silurian strata (Llandovery) are found in place. This conjecture may perhaps strengthen the inference that seems to be indicated by the shore-section between Duffcarrick and Ballymoney above described.

In the ground hitherto mapped as Lower Silurian, to the north-west of Balbriggan, fossils of Wenlock age were last year obtained. Another traverse was made by Mr. McHenry of the high ground lying to the W. of Newtownmount-Kennedy, with a view to determine to what extent the "green grits and slates" of the published maps were of sedimentary origin. From the examination of a limited area it would appear that these rocks are mainly basic igneous masses of andesitic types (calc-diabase).

Towards the close of the season, Mr. McHenry and Mr. Seymour visited the dyke-region of Co. Down for the purpose of determining the relative extent of the basic and acid intrusions in that part of Ireland. A detailed account of the petrographical results prepared by Mr. Seymour will be found at p. 161.

Counties Kilkenny, Waterford, and Wexford.

Mr. J. R. Kilroe.

The revision of the Silurian tracts of the extreme south of Ireland has been completed by Mr. Kilroe, who has joined up

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his boundary-lines with those traced southward by MR. MCHENRY. In regard to the sedimentary rocks, he reports that west of the Barrow in Kilkenny they are almost destitute of fossils. Only a few slender iron-stained stems and fucoid markings have been found in the fresh rock of the sections laid open in the cuttings of the extension railway now being made from New Ross to Waterford. In Wexford, MR. CLARK confirmed the occurrence of fossils in some localities in the vicinity of Duncannon and Arthurstown where they were formerly obtained, and discovered a new locality, three miles west of Wellington Bridge (Sheet 169), near Ballinruane House. It would appear that a zone of Lower Bala rocks strikes north-eastwards from Duncannon; and that another zone characterised by a somewhat higher facies of fossils extends from Ballyhack (Sheet 168) towards Burkestown Cross Roads. At Waterford, the dark gray slate and grit series of Gibbett Hill has yielded double graptolites of Bala age; and, according to the lists published in the Survey Memoir, and more recently by MR. COWPER REED, the strata of the well-known locality of Raheen near Newton Head on the Barrow Estuary, are of the same age. Mr. J. R. Kilroe.

It is probable that southward from the strike line of the Silurian strata, running east by north from Waterford across to the Old Red Sandstone, and on to Duncannon in Wexford, Bala rocks prevail—possibly to the exclusion of other divisions of the Silurian series. No strata possessing the usual characteristics of the Llandeilo group have been met with within the zone. Black slate occurs in many places in the district, but without fossil evidence it cannot be shown to be lower than the Bala group, which in this region includes much black slate containing Bala fossils. Graptolites of the species *G. Hisingeri* are reported to have been found in the dark gray slate a little north of Bagginbun (Sheet 180)*, but recent re-examination has failed to confirm this statement, and no means now exist of verifying the determination of the species.

Two small inliers of Silurian strata, surrounded by Old Red Sandstone, occur to the south and south-west of Mullinavat. They consist of green, greenish-gray, and dark gray slates and grits, which so far have not yielded any fossils. The grits contain a good deal of felsitic matter, and it is worth noting that adjoining the basic igneous mass, shown in the Rathkieran inlier, lies a breccia of igneous materials, which does not seem to be fault rock. This rock shows a structure which resembles bedding, but its exact relation to the igneous mass has not been determined. The latter is in parts vesicular. Round the larger bosses of granite where the Silurian grits and shales have undergone alteration, the development of mica becomes well-marked as the strata are traced towards the igneous rock. Spotted schist has been noticed at a few points within the metamorphic fringe. Schist, with fairly well-formed crystals of chiastolite, occurs on the high road at Brownsford, and at the farmyard of Newgrove House, south-east of Inistioge.

* Memoir on Sheets 169, 170, 180, 181, 41 59.

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Mr. J. R. Kilroe.

During the revision of the Silurian tracts of this part of Ireland, as in the regions further to the north, advantage has been taken of the opportunity to re-examine the igneous rocks which play so large a part in the geological structure of County Waterford. The results of this re-examination have been briefly stated in previous *Summaries of Progress*. The work of last year has confirmed the results already obtained. There can be no doubt that here, as in Wexford and Wicklow, many of the rocks which have been mapped as felstone-lavas are really intrusive bosses and sills, and that some at least of the "ashes" are not tuffs, but crushed andesites or felsites. At the same time clear evidence can be found that true andesitic and felsitic lavas and tuffs are intercalated in the Lower Silurian series of Waterford.

Reference was made in the *Summary of Progress* for 1899 to the green grits and conglomerates which overlie and are partly made up of fragments of the andesites that occur at Ballyscanlon Lough. Some of the coarser sediments, such for instance as those at Cullen Castle, are probably volcanic agglomerates that may mark some of the volcanic vents of the time. Similar green fossiliferous grits and slates occur at Knockmahon and along the coast to Ballydowane Bay. The occurrence of these rocks, composed in large measure of volcanic detritus, yet containing undoubted Bala fossils, points to volcanic action, probably on an extensive scale in this part of Ireland, during the deposition of the Bala division of the Silurian system. Further interesting corroboration of this conclusion was obtained by the Director-General, who supplies the following notes of his observations along the coast-line during his tour of inspection last year.

Director-General.

"The rocks on the shore at Knockmahon consist of fine purple and green grits, with corals, brachiopods, and fragmentary fossils. They rest on the uneven surface of an amygdaloidal and nodular rock, probably an andesite, which may represent one of the lavas of Bala time. Some of these fragmental strata closely resemble the remarkable breccias which have been described as occurring near Dunhill Bridge, save that they are crowded with well-preserved fossils which are absent in the Dunhill breccias.

"Much clearer in its evidence is the section exposed at the base of the cliff on the western side of the little bay, immediately to the west of Bunmahon Head. There an augite-andesite rises from the beach, and displays a characteristic development of the ellipsoidal or pillow-shape structure so characteristic of many basic and intermediate lavas of Palæozoic and later periods. The ellipsoids are irregularly ovoid in shape, and vary from a couple of inches to two or three feet in diameter. Many of them show a finely vesicular external layer or shell. In the interspaces between them, to a depth of at least three feet from the upper surface of the lava, fine sediment has descended from above. This material has solidified into a compact felsite-like substance, in which traces of stratification may be detected. It has evidently been washed from above at the time when the lava lay under water and presented a surface of elliptical blocks,

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either loose or only slightly attached to each other. Above the andesite comes a thick series of well-bedded volcanic grits like those of Knockmahon. The stratification is well shown by the parallel stripes of darker and lighter tint up the face of the cliff, the inclination of the strata being towards north-west at 15 deg. Some of the more flinty bands correspond with the felsite-like material that has filled up the interspaces between the ellipsoids of the underlying lava. Director-General.

"The geological record revealed in this section appears to me to be of the highest interest in regard to the interpretation of the whole volcanic history of this region. It proves the existence of a true lava covered by fine tuffs and volcanic grits contemporaneously associated with the Bala rocks of the coast. I was particularly struck with the felsitic aspect of some of the finer bands in this series of sediments, and with the deceptive resemblance to intrusive veins presented by the similar material between the lava-ellipsoids. This material recalled some of the finer and apparently felsitic portions of the agglomerates further east, which here and there invade the surrounding rocks. In the present instance there could be no doubt of its clastic origin, and one could not but suspect that some at least of the agglomerates between Knockmahon and Tramore may after all, notwithstanding the strikingly felsitic character of their matrix, be pyroclastic rocks, and not felsites brecciated *in situ*. For the purpose of testing this question by the help of the microscope I requested Mr. Seymour, who accompanied Mr. Kilroe and myself in this visit, to have some thin slices cut from the most flinty parts of the fine material filling up the interspaces in the Bunmahon andesite, and to compare it with the fine matrix of some of the agglomerates further east. He has supplied the following report of his examination:—'The yellowish-grey banded rock filling up the interstices in the "pillow lava" W. of Bunmahon Head and regularly stratified on top of it, is in section a typical, fine-grained tuff. The base, though almost felsitic in places, is certainly fragmental, and is composed of the very finest felsitic (devitrified glass) particles, the clastic origin of which is, however, more apparent as the size increases. It contains numerous fragments of quartz, some of them containing glass-inclusions, and many of them showing conchoidal fracture. A few fairly basic plagioclases occur, and are probably derived from the breaking-up by volcanic explosions of a rock similar to the under-lying lava. A few pieces of a flaggy devitrified felsite occur in the section, also some greenish patches of chloritic matter. The rock is, on the whole, decidedly acid in composition. It is practically identical in every way with the fine-grained matrix of the Dunhill tuff, and compares very closely with the base of the agglomeratic rock near Sheep Island.* That rock is pyroclastic, and its matrix is in places very like that of the rock from Bunmahon.'"

Another striking series of dark green volcanic grits occurs 5 miles to the north-west of Tramore, in the north-western Mr. Kilroe.

* *See Summary of Progress* for 1899, p 80.

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Mr. Kilroe.

portion of Sheet 179. The grits contain numerous fragments of light gray felsite, many of which are rounded, and in general showing flow structure, embedded in a clastic matrix which is often very compact in texture. Bedding is seldom to be observed, though a more or less perfect cleavage traversing the mass gives the appearance of stratification. This series seems to be invaded by the felsite which bounds it eastward, and possibly also by that which bounds it on the N. and S. Similar green grits stretch north-eastward from Ballynamona towards Mount Druid (Sheet 178), near to which the fragmental rocks are associated with a vesicular basic mass. Fragmental rocks of the same character appear on each side of the Barrow at Ballinlaw Ferry, N. of the junction of the Barrow and the Suir.

An interesting section has long been known to be exposed on the coast of Waterford Harbour, at Raheen, near Newtown Head, where the best succession of volcanic rocks in the district is associated with fossiliferous strata of Lower Silurian age.* These rocks comprise spherulitic and flow-structure felsites; gray tuffs and volcanic grits, and dark grey sandy fossiliferous grits.

The horizon in the Lower Silurian of these rocks is fixed by the fossils in the associated grits. Mr. Cowper Reed in his paper cited below appears to ascribe the series to Lower Caradoc, placing it just above the *Dicranograptus* zone of Wales. He considers also that local facts in the Waterford area justified him in placing the zone mentioned, and consequently the Raheen rocks, at a higher horizon than the Tramore limestone. Mr. Kilroe, however, believes this limestone to be of Bala age, and that the Raheen series stands at least equally high in the formation. The occurrence of limestone and calcareous grit similar to those of the Tramore series, in the volcanic succession at Newtown Head, and the fact that a slight divergence is noticeable between the fossil facies of the Tramore and that of the Raheen series, would seem to indicate that the latter represents a higher horizon than the former, as indeed Mr. Reed, upon other grounds, maintains. If this be so, the Raheen series might be regarded as belonging to the Upper Bala (Caradoc) period.

On the Wexford side of the estuary opposite Cheek Point, and inland four miles east by north, near Killesk Cross Roads, gray grits are associated with fragmental rocks which may be true tuffs. On the shore of Great Island also opposite Cheek Point tuff-like rocks occur in proximity to gray grits, with bedding conformable to small limestone bands.

The true lava-form characters of the sheets seen on the Raheen shore may be taken as a guide in the interpretation of similar inland rocks, of which the relations are much less clearly seen. Thus the felsites near Dunbrody and near Waterford with flow-

* See Survey Memoirs, Explanation of Sheets 167, 168, 178, and 179. Ireland, pp 25, and 41. The Section has recently been described in much more detail by Mr. F. R. Cowper Reed, *Quart. Jour. Geol. Soc.*, vol. lv. (1899), p. 721.

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structure and fragmental accompaniments are probably lava-flows. Mr. Kilroe.

Some of the felsite masses in South Waterford and Wexford contain detached portions of basic material, possibly including fine grained grits. This may especially be seen in, though not limited to, the case of the light greenish-grey felsites which form the rugged track extending from Sugarloaf Rock (Sheet 168), south-westward towards Ballyphillips (Sheet 179), particularly at Sporthouse and some 50 yards north-west of the point where the roads cross, half a mile east by north of Shinganagh Cross Roads. These felsites, however, are not very distinguishable from those which seem to be earlier, though, on the whole, they are more coarsely crystalline in texture. If they are classed amongst the youngest acid rocks in the region, they may correspond in age with those which pass into granite and "elvanite" near Mount Druid, and on the east side of the Barrow (Sheet 168).

Besides a narrow band of granite which extends from Mount Druid north-eastward, and resembles a fine-grained variety of that of the Dublin and Wicklow range, a few granite protrusions of probably the same age appear in south-west Wexford, and at Rochestown in south Kilkenny. At the last-named point the granite is quite like that of the range; while the few small outcrops east of Dunbrody are quartz-felspar rocks with granitic texture, almost if not quite devoid of mica. They are represented as "elvanite" on the published map.

The results of MR. SEYMOUR'S study of the petrography of the Silurian districts of the south-east of Ireland will be found on p. 165.

In conclusion, it may be repeated here that the re-examination of the igneous rocks which has been made during the revision of the Silurian tracts of the south-east of Ireland has shown that considerable modifications will be necessary in the representation of these rocks upon the published maps. In particular, the areas occupied by the intrusive masses will require to be considerably extended, and those of the lavas and tuffs to be proportionately reduced; the petrography will need revision, many of the so-called "felstones," for example, being undoubtedly andesites, and the agglomerates will require to be discriminated. But such a thorough revision of the ground would really amount to a re-survey, and would take several years of sedulous work both in the field and in the laboratory. In view of the other pressing duties of the Geological Survey of Ireland, it has not been deemed expedient to undertake this labour for the present. It must remain as one of the tasks of future years. Director-General.

Devonian.

CORNWALL.

In continuation of his previous field-work, MR. USSHER has been engaged in the districts of Pillaton and Liskeard in East Cornwall, in mapping the Middle and Upper Devonian rocks, and the Lower and Middle Culm-measures. Mr. W. A. E. Ussher.

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Mr. W. A. E. Ussher.

The discovery made in 1899 of the identity of the Polperro beds with the Dartmouth slates necessitated the insertion of a boundary for these beds throughout the Lower Devonian area. This boundary had been drawn in the Kingswear promontory, where it is well marked, during the survey of that district, and in the Looe district in 1899; but, in the intervening area, it is often exceedingly indefinite and uncertain.

The identification of the fossiliferous rocks of Looe, in Devonshire, is a matter of still greater importance. In that district the stratigraphical evidence for the relative position of these rocks and the Polperro beds (or Dartmouth slates) proved to be inconclusive. The settlement of this question would resolve all the doubts entertained as to the stratigraphical succession and the structure of the Lower Devonian areas throughout South Devon and Cornwall.

Lithologically, and in their modes of association with the slates in which they occur, the fossiliferous rocks of Looe have their counterparts in the Torquay promontory, in the Kingsbridge district, and in other parts of the Lower Devonian area. Palæontologically, the distorted fossils at Looe are regarded as Gedinnian;* whilst those of rocks of similar lithological types, in Devon, belong to much higher horizons in the Lower Devonian, viz., Upper and Lower Coblenzian. Amongst the Looe fossils identified by DAVIDSON are *Rhynchonella pengellyana*, Davidson, and *Spirifer primævus*, Steininger. The first named is given by SANDBERGER, with six other fossils, as occurring only in the Onychian Sandstone (the base of the Lower Devonian), and in no newer subdivision of the Lower Devonian. *Spirifer primævus* is given as common to the Onychian Sandstone and the overlying Rhipidophyllen or Hunsrück-Schiefer.

In his "Supplement to the British Devonian Brachiopoda," p. 4, DAVIDSON, referring to fossils collected by the REV. G. F. WHIDBORNE from the Lower Devonian beds in Saltern Cove Railway-cutting, observed:—"I thought I could recognise among them *Spirifera lævicosta*, *Rhynchonella Pengellyana*, *Leptæna Looiensis*, *Orthis hipparionix*." The strata in Saltern Cove Railway-cutting are, certainly, above the Dartmouth slate series, and are unhesitatingly regarded as a part of the Cockington beds (Coblenzian). The fact that the fossils referred to in the above quotation were casts would equally apply to the original specimens from Looe. The fossils collected in the Looe district in 1899 were sent up to Jermyn Street, together with fossils from Torquay obtained in the past year. Amongst the Looe fossils is *Spirifer primævus*.

During the survey of the Kingsbridge area, crushed impressions of Spirifers resembling *S. primævus* were obtained at Ringmore

* Doubtfully correlated by SANDBERGER with the Grauwacke of Montigny in the Ardennes, the Rhipidophyllen Schiefer of the Hunsrück, Eifel, and Taunus districts, and the Siegen grauwacke of Nassau. *Jahrb. d. Nass. Verf. f. Nat. Jahrg.* 42.

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and elsewhere. At Ringmore a large eye of Phacops, which DR. WOODWARD thinks may belong to *P. Ferdinandi*, was also found. These fossils, with others, from rocks in Devon and Cornwall which correspond in character with the various types of the fossiliferous rocks of the Looe district, will be submitted for examination by the Geological Survey Palæontologist. Mr. W. A. E. Ussher.

As regards the Torquay promontory, greater experience, obtained since the original survey in 1888, has enabled MR. USSHER to detect an unfaulted junction between Middle and Lower Devonian strata, and to recognise Lower Devonian types met with in other parts of the area.

In the south-west of Cornwall MR. WILKINSON has mapped the sedimentary rocks between Whitecross, near St. Erth, to Leedstown. These strata are regarded by MR. HILL as belonging to the fourth or Mylor subdivision of the rocks in the Falmouth district. Mr. Wilkinson.

In continuation of the work of previous years, MR. HILL has pushed westwards the survey of the area enclosed between Helford River, Gerrans Bay, and the upper estuaries of the Fal, towards the metalliferous districts, of which Camborne and Redruth form the principal mining centres, and he has commenced the examination of the mineral tracts themselves. Mr. Hill.

The sedimentary rocks met with comprise lithological divisions the broad characteristics of which have been sufficiently described in former Summaries. They consist of the Portscatho, the Falmouth, and the Mylor series. The igneous rocks include "greenstones," mica-traps, granite, and elvan.

The fact that the whole of this area contains nothing in the nature of a limestone, as well as the apparent absence of organic remains, become easy of explanation when it is realised that the strata form only a thin series which occupies a considerable breadth of country owing to a constant repetition by means of isoclinal folds. Besides the evidence of such plication, which is amply demonstrated by the results of the systematic mapping of the district, ocular demonstration of these structures may sometimes be seen in natural cliff sections.

The occurrence of "greenstones" in this district, so far as yet surveyed, is limited to ground between Devoran Creek and the eastern boundary of the Penryn granite.* These rocks are generally so far decomposed, and the sections so meagre, that neither their mineral composition nor their relationship to the rocks amongst which they occur can be satisfactorily determined. Originally they were probably dolerites, and possibly intrusive. One band of them remains in a fresh condition, probably owing to its original massive character. It is seen at Lower Treluswell and other localities. It is about 60 yards wide and follows an horizon parallel to the boundary of the granite, from which it is only divided at Burnthouse by a space of 150 yards, in which

* For the purposes of this Report the large mass of granite occupying so much of the broad tract of country between Redruth, Helston, and Penryn will be referred to under this designation.

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Mr. Hill. another "greenstone" of the decomposing type common to the district may be observed.

In petrographical character it is an amphibolite, which at Burnthouse is coarse in texture, and presents on its outer portion a compact fine-grained aspect and is equally fresh. Neither the coarse-grained interior nor the finer-grained margin exhibit any traces of foliation. Between Burnthouse and Ponsanooth the band is quarried for road metal. In this quarry the rock is seen to be a homogeneous amphibolite, green in colour, being made up almost entirely of a fibrous hornblende, the individuals of which often attain a large size, and the crystal faces occasionally exhibit a bronzy lustre. The mass, as seen in the quarry, shows no schistosity whatever. Between this quarry and the Burnthouse exposure a variety is seen which weathers in a coarse nodular form, and in which felspar is seen to be intermixed with the hornblende, but plays a subordinate part in respect to that mineral.

At Burnthouse the finer grained "greenstone" has also been quarried. This rock occurs about 90 yards from the amphibolite, and must have a width of at least 30 yards. It cannot be many yards from the margin of the granite. This mass is in a highly decomposed condition, and is sheared throughout. Its relations to the amphibolite bands are not clearly visible. Its position in the field would naturally suggest some connection with the amphibolite, but it has been entirely crushed down by shearing movements, while the latter has been to all appearance unaffected. While the massiveness of its structure would sufficiently protect the main body of the amphibolite, it is difficult to see how its marginal portions could have escaped those processes of deformation which have so profoundly modified the "greenstone" band adjoining. The study of the tectonic features of the district has certainly shown marked differences of behaviour under stress between rocks which are homogeneous and those of heterogeneous character; while the latter have been broken down the former have remained intact. The suggestion may be offered that possibly the amphibolite, which is composed almost entirely of hornblende, owes its immunity to this cause, and that the "greenstone" which is broken down, being composed, like the other sheared varieties of the district, of a mineralogical mixture in which felspar has been generally an important ingredient, owes its deformation to its heterogeneous composition.

It may be remarked that all the "greenstone" bands so far mapped in the district are found in the Mylor series, and that both the bands which have been here described occur in the aureole of contact-alteration which encircles the granite mass, and to which allusion will be made later. While "greenstones" are associated with the Mylor series, the Portscatho division contains within its limits an assemblage of mica-traps, which have marked resemblances in the field to the lamprophyres that occur amongst the schists of the Scottish Highlands. They have been noted exceptionally in the Falmouth series, and one is seen to pierce the Nare Point conglomerate.

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Mr. Hill. Although these mica-trap sills are everywhere in a highly decomposed condition, they are markedly different from the "greenstones." Nothing in their appearance suggests metamorphism. The type of alteration which they have undergone is rather that of decomposition under atmospheric influences. These rocks present a rusty brown aspect in the field, and are so weathered that fresh specimens have not been obtained, and they have not yet been submitted to microscopic examination. They occur as sills amongst the slates, on which they have effected a limited amount of contact-alteration, confined to indurating and sometimes converting them into hornfels to a distance of 6 or 9 inches from the edge. The same mass which lies between the strata as a sill may suddenly divert its course and behave as a dyke, and small veins have been discharged from them into the adjoining strata. They vary from a foot in width to 50 yards. In many instances spheroidal weathering may be observed among them, cores of more solid material being encircled by concentric outer layers of exfoliating material. Flow-structure is not uncommon, being especially noticed in the finer-grained marginal portions. In some rocks exhibiting flow-structure the spheroidal cores are elongated in the direction of flow, while rounded inclusions of quartz may be seen with their long axes in a corresponding position. Notwithstanding the advanced state of decomposition, the ground mass of these rocks can generally be seen to consist of a medium-grained admixture of biotite and felspar, while inclusions of quartz and crystalline felspathic rock are characteristic. Inclusions of slate are also frequently seen. The quartz and felspar-inclusions vary considerably both in size and shape. The quartz has been observed in masses as large as 9 inches, which grade downwards to the smallest dimensions. The inclusions both of quartz and felspar have often been perfectly rounded, while in other cases they have a brecciated appearance. Sometimes both quartz and felspar occur in perfectly rectangular fragments. These rocks vary considerably in their texture, some being as coarse as large-grained dolerites while others assume the texture of basalt. The mica-traps probably vary in acidity; in some the undecomposed cores seem to be made up altogether of felspar. In one of them which is deeply weathered and contains these acid cores, the mica is white, probably due to bleaching. Although quartz is so prominent as included individuals, it does not appear to enter into the composition of the matrix. In the largest and coarsest sill, although the texture of the rock is fine towards the margin, the biotite crystals retain their normal dimensions.

These mica-traps would appear to have been intruded after the slates had been cleaved but before the cessation of the stresses, which have acted on a part of the crust sufficiently within the zone of fracture, that instead of the strains finding relief in a system of fissures more or less divided, the mass has been everywhere free to give way, so that the entire crust is minutely fractured and converted on a large scale to what may

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Mr. Hill. be termed a regional breccia. Consequently these rocks occur as discontinuous patches, and cannot be followed for more than a short distance. Some of the joints of the sills are parallel to the movement planes in the adjoining slates, and there is a tendency to a parallel structure corresponding with these joints. Many instances may be observed where the minor faults in the slates have also affected the mica-traps and heaved them. These rocks, besides being affected by fractures subsequent to their consolidation, have sometimes been injected into brecciated strata, so that what would have been a single sill is represented by two or three discontinuous veins. Moreover, brecciation has continued after the consolidation of the erupted material, the slate along the margin exhibiting a curious zone of very fine brecciation which has been brought about by stress acting on the indurated margin that has been hardened by the sill.

Old Red Sandstone.

SOUTH WALES.

Mr. A. Strahan and Mr. Cantrill. In carrying on the surveying of the South Wales Coalfield it has been necessary to map the outcrops of the older rocks which fringe the Coal-Measures to the north and south. The district on the north side in Carmarthenshire, which has been surveyed by MR. CANTRILL, comprises the summits and northern slopes of the Black Mountains, and extends from the Twrch Fechan to the village of Trapp, near Llandeilo. The three subdivisions into which the Old Red Sandstone was separated near Abergavenny have been found to hold good also in the area now under examination. They consist in ascending order of:—

1. The Red Marl series, which includes a great thickness of red marls, frequently hard and sandy, with occasional thin beds of soft micaceous and hard gritty sandstone up to 10 feet in thickness. Many of the marl-beds contain small calcareous nodules, sometimes in such abundance as to become cornstones, and to resemble conglomerates. Such beds are well exposed in the Sawdde, and are to be seen in numerous brooks between Gwynfe and Trapp. The red marls rest on the green micaceous "tilestones" or uppermost group of the Silurian series, and themselves contain Silurian fossils for a distance of 5 or 6 feet above their base.

2. The rocks which constitute the main mass of the upper part of the Old Red Sandstone include at their base a series of pale-green and dull-red micaceous sandstones with subordinate marls and nodular cornstones. This green series forms cascades in the Sawdde Fechan, and is exposed in the Clydach, but especially along the valley of the Cennen. The sandstones have been quarried occasionally for walling, paving, and drain-tiles. Upwards the green rocks pass into a considerable thickness of alternating red sandstones and marls which form the greater part of the scarp-slope of the

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Carmarthen Fans. About 50 feet below the top of the red sandstones there is a marked conglomerate, which is 10 feet thick at Careg yr Ogof, and consists of pebbles of vein-quartz and pale-red or green quartzite imbedded in a hard red siliceous matrix. The pebbles range up to 4 inches in length. This conglomerate and the red sandstone above it form the long dip-slopes running southwards from the Fans of Brecon and Carmarthen, but they gradually disappear westwards, so that the overlying subdivision or Grey Grits rests directly on the beds below. At the same time the Old Red Sandstone ceases to form the predominating scarp, the main line of Fans consisting of Mountain Limestone and Millstone Grit. Whether the disappearance of the red grits and conglomerates is due to an overstep by the Grey Grits, or to thinning out without unconformity, cannot yet be stated. Mr. A. Strahan and Mr. Cantrill.

3. The Grey Grits and conglomerates vary from 6 to 30 feet in thickness. The lower beds are usually a white conglomerate charged with pebbles of white vein-quartz ranging up to nearly 3 inches in length. Upwards they pass into yellow sandstones and sandy shales which themselves merge into the Lower Limestone Shales. The white conglomerate closely resembles the basement-beds of the Millstone Grit. This subdivision is exposed on Careg yr Ogof, on the Twrch Fechan, and has been traced without interruption as far as Trapp, but appears to be thinning in that direction.

The Old Red Sandstone south and west of Gwynfe is traversed by several folds which have a general direction of W. 20 deg.—30 deg. S., and are therefore parallel to the strike. One of these, a faulted syncline, throws down the outlier of Carboniferous Limestone known as Careg Cennen into the valley of the Cennen some distance to the north of the limestone-escarpment. The lowest beds of the Old Red Sandstone, together with the Upper Silurian strata, are vertical or nearly so, and high dips prevail up to and beyond the base of the Carboniferous rocks. Measurements under such circumstances are difficult, but as far as our observations go, the Old Red Sandstone appears to be thicker along its northern outcrop than at Cardiff, and therefore to expand in the direction in which all the Carboniferous rocks lose thickness.

In the south crop the Old Red Sandstone has been examined by MR. TIDDEMAN as far as the western margin of Sheet 247. He finds no satisfactory section showing the sequence into the Carboniferous Limestone, but obtains evidence of overthrusting, by which the Old Red strata appear to have been pushed over the limestone. The rock seen is a very coarse conglomerate, with an abundance of pebbles of white and pink quartz and some other materials. The general trend of the anticline by which it is brought to the surface is E.S.E. and W.N.W., and it also runs through Cefn-y-bryn, a fine Mr. Strahan and Mr. Tiddeman.

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Mr. Strahan and Mr. Tiddeman.

ridge rising to a height of 600 feet. In Three Cliff Bay the conglomerate is faulted against much-dolomitised thin-bedded limestones, which probably lie low down in the limestone-series, but above the Lower Limestone Shales.

Inverness-shire.

Mr. Horne.

From his station at Daviot Mr. Horne was in a favourable position for studying and mapping the base of the Old Red Sandstone in Strath Nairn. He reports that the basement of the conglomerate in that district presents remarkable evidence of its derivation from the crystalline rocks of the immediate neighbourhood. To the north of Loch Duntelchaig, and near its outlet, where the muscovite-biotite-gneiss is largely developed, both the matrix and the included blocks of the conglomerate have come mainly from that rock. Again, further down the valley of the Nairn, west of Mains of Faillie, the conglomerate is chiefly composed of granitic detritus. The larger pebbles consist of porphyritic biotite-granite, resembling that *in situ* on Beinn a' Bheurlaich, two miles to the east, which forms a part of the Moy mass. These are associated with small subangular blocks of micro-granite, porphyrite, quartz-porphyry, lamprophyre and granulitic gneiss. The matrix is a coarse arkose, derived presumably from the disintegration of granitic rocks.

Ross-shire.

Mr Peach.

The mapping of the older rocks in the Eastern part of Ross-shire continues to reveal occasional outliers of Old Red Sandstone, which prove the former wide extent of that formation and the great denudation it has undergone. Mr. Peach reports that the mass of coarse breccia which caps Ben nan Cabag, north of Loch Luichart, partly reported upon last year,* and originally discovered by Mr. Gunn† occupies a much greater area than was at first anticipated. Two smaller outliers, one only a few square yards in extent, lie between the Ben nan Cabag outlier and the Black Water. A third, which crosses the Black Water in line with these, about midway between Altquoich and the foot of Strath Vaich, may possibly be a tongue-like extension of the larger outlier of Meall a Ghrianain formerly noticed by Mr. Gunn.‡

Caithness.

Mr. Peach and Dr. Crampton

The tract of Old Red Sandstone mapped last season by Mr. Peach and Dr. Crampton extends as a broad strip across Caithness from the coast at Wick to Georgemas. In this area Mr. Peach reports that the main rock-type is a micaceous sandy argillaceous flagstone, often bituminous and generally containing

* *Summary of Progress* for 1899, p. 95.

† Annual Report of the Geological Survey for 1896, p. 53.

‡ *Loc. cit.*

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more or less lime and iron-carbonate. When this rock is thinly and evenly bedded it constitutes the celebrated Caithness Flagstone of commerce. By admixture of different sediments it passes into flaggy sandstones, shales or mudstones, locally known as calmstones, or even into an almost pure limestone. Mr. Peach and Dr. Crampton.

Some of the flags and shales are so bituminous as to become impure oil shales, while albertite or mineral pitch is found distilled out into the faults and cracks of the strata over large areas in the western parts of the district. Marcasite and iron pyrites occur frequently as nodules throughout the series. Intercalated with the flags and shales are occasional beds of nearly pure sandstone, devoid of flaggy character. A small area of red or brown sandstone or coarse arkose and conglomerate or breccia is found at Houstry, near the southern edge of the area mapped. The colour of the rocks is for the most part a leaden grey, which becomes darker by the admixture of carbonaceous matter. The limestones are generally bluish grey, while the shales are usually lighter in colour than the flags. In the eastern district many of the rocks are of a greenish tint. All the rocks are liable on exposure to assume an ochreous colour from the decomposition of the iron-carbonates and sulphides contained in them, particularly in the neighbourhood of lines of crush, while near some of the faults and veins the rocks are liable to become bleached, and in places reddened by hæmatite.

Throughout the whole series of strata, sun-cracks, rain-prints, and other surface-markings occur on most of the bedding-planes, whence the inference may be drawn that the original sediments were laid down on a sinking floor, and were subjected to repeated periodical desiccation.

Along fault-lines, in addition to carbonates and quartz, the veins sometimes carry galena in small quantity. A few barytes-veins occur on the cliffs near to the Old Castle of Wick.

An important structural feature has been found in a line of fault which, with a trend from north to south, enters the area a little to the east of Castletown, and passing southwards by Hall of Durran, Bower Station, Old Hall of Dunn, leaves it on the crest of Backlass Hill. This is evidently the continuation inland of the fault which passes out to sea to the north of the village of Brough, and which has there the effect of bringing the Caithness flagstones on the east into conjunction with the overlying yellow Upper Old Red Sandstones of Dunnet Head on the west. From the nature and the amount of disturbance of the rocks on each side of the line of dislocation all along its course, the fault may be recognised as having been produced by an upthrust from the east. That the amount of displacement must be great may be inferred from the fact that everywhere the rocks on the two sides of the line are totally different from each other. The actual amount of upthrust is still unknown; but further investigation in adjoining areas may furnish a clue to it. In the meantime the line of fault supplies a convenient division of the ground into two unequal parts, which may be conveniently described separately. In the western or smaller subdivision the

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Mr. Peach and Dr. Crampton.

rocks are all more finely and evenly bedded than in the eastern and it is especially to be noticed that all the workable flagstones are confined to the west of the line. A few coarse flagstones are worked at Stonehone near Watten, on the east side, but they are very inferior, and are only used locally.

The lowest strata in the western sub-division are found near its south-west corner, in the neighbourhood of Achanarras. They consist of flagstones and flaggy limestones which have yielded a rich fish-fauna identical with that found south of the Moray Firth and in the Stromness district of Orkney.* They are almost horizontal at Achanarras, but with a tendency to dip towards the north and north-east. In the direction of dip these strata are succeeded by an alternation of flagstones and shales or calmstones, dipping in the same direction at angles of from 2 deg. to 5 deg. for about four miles. It is in this set of strata, at a level of about 200 to 300 feet above Achanarras, that the celebrated flags of Spittal occur, while those of Banniskirk lie, probably, a little higher still above the strata to be seen in Achanarras quarry. Near Georgemas Station a synclinal axis has been detected, north of which the flagstones dip gently to the south-east, and after rolling about or lying nearly flat for miles across a wide dome-like expanse corresponding with the hills of Stemster, Achingills, Hilliclay, and Olrig, they finally roll over on the north slope of the Hill of Olrig, and dip steadily towards the N.N.E., the highest beds occurring on the shore between Thurso and Clardon Head, outside the present area. The celebrated quarries of Stonegunn and Weydale lie just at the margin of the area now reported upon. The structure is, therefore, that of a syncline, the axis of which runs in a curved direction more or less E. and W. through Georgemas, and a dome to the north, the centre of which corresponds to the top of the high ground behind Stemster Hill. The fishes found in the Spittal and Banniskirk quarries are common to the Achanarras and Thurso beds. *Thursius macrolepidotus* occurs at Clayock, while DR. CRAMPTON obtained *Coccosteus minor*, a zonal form of the Thurso beds in the syncline to the N.E. of Georgemas Junction.† *Osteolepis microlepidotus* is found at Stonegunn and Weydale, and together with *Coccosteus minor* at Murkle. These two fishes are typical forms of the Thurso fauna. The strata at Achanarras quarry lie at least 900 or 1,000 feet below those from which DR. CRAMPTON obtained *Coccosteus minor*. MR. PEACH and he are therefore inclined to place in the Thurso group all the strata in the present area lying to the north and east of a line drawn a little to the north of Spittal and Banniskirk. All these rocks are in turn truncated by the fault. As they approach it they gradually swing round and dip towards it, but still nearer to it they bend

* See Dr. Traquair's paper in *Proc. Roy. Phys. Soc. Edin.*, vol. xii., part 2, p. 279.

† The determination of these forms in the field by the Survey Officers has been confirmed by Dr. Traquair.

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up and dip steeply away from it, while in some cases they are even overturned. In a quarry on Corsback Hill the flagstones, which dip generally towards the east, show at intervals, lines of "staving" and overfolds accompanied by small overthrust-faults pointing to movement from the east. Mr. Peach and Dr. Crampton.

Owing to the absence of fossil evidence the horizon of the strata on the east side of the fault is not yet known. Possibly the true structure of this ground will not be made out till the coast lines are studied in detail. The evidence afforded by the exposures in the area examined last year is that in the neighbourhood of the fault the strata are thrown into a succession of sharp folds, all of which have steep limbs towards the west, while some of them are overfolds. Small overthrust faults are also numerous. These phenomena are well displayed in the railway cutting near Bower Station. Similar structures occur on Backlass Hill and Houstry, at the south end of the line, where the lowest strata in the whole area are to be found. These consist of brown sandstones, arkose, and coarse conglomerate or breccia made up chiefly of fragments of granulitic "Moine"-like schists and granite*. They indicate that a local base of the series is here brought up near to the surface; they may represent a portion of the Berriedale Flagstone group. Beyond the immediate influence of the fault the strata, which are grey and dark, almost black, coarse-bedded flagstones with flaggy sandstones, dip persistently towards the east at low angles for about 4 miles, when they turn up for a short distance and dip westwards. A line of structure like that accompanying the great fault is then encountered, running approximately N. and S., the corrugated and shattered strata seamed with iron-carbonate being well displayed in streams at Croft of Quoy Brae, and also near Bilbster House. East of this line the beds dip gently eastwards to within about a mile and a half from Wick, when they once more bend up and dip westwards as far as the coast. On this limb of the syncline the strata are much more steeply inclined than on the western one, sometimes reaching an angle of 25 deg. The structure of this portion of the area is that of a double trough with approximately N. and S. axes, the line of upthrust fault representing the dividing anticline. The trough of the western syncline is close to the fault. The horizon of the highest beds is at present unknown. To what extent these strata are repeated on the east side of the fault can also in the meantime be merely conjectured; but near Ackergill, in the centre of the more easterly trough, Dr. Flett found a specimen of *Coccosteus minor*. Dr. Traquair states that the fish which have long been known from the South Head of Wick, on the eastern limb of the syncline, and far beneath the Ackergill beds, are *Dipterus valenciennesii* and *Thursius macrolepidotus*. *Coccosteus decipiens* also occurs between Wick Bay and Noss Head. Dr. Traquair regards the Wick and Ackergill beds as being the equivalents of part of the

* Dr. Flett, while making traverses in this district during the past year, observed these rocks and noted their significance.

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Mr. Peach and Dr. Crampton.

Thurso group. If this view be correct there must have been a great difference in the sedimentation of the two areas, as the Wick beds consist of alternations of flaggy sandstone with occasional true sandstone, almost pure limestones, calmstones, and few or no real flagstones. It seems as if the Thurso district lay in the centre of the basin in which the peculiar type of sediment of the Caithness and Orkney phase of the Old Red Sandstone was deposited. Before these points, however, are settled a much larger area of the county will require to be surveyed. Systematic fossil-collecting continued over a period of years seems to be the only method of gaining the required evidence.

ARGYLLSHIRE.

Mr. R. G. Symes.

The mapping of the Old Red Sandstone series in the district of Lorne was continued last year by MR. SYMES. In the course of his survey he found to the west of Kilmelfort no trace of the basement conglomerate and sandstone that may be looked for at the base of the volcanic series, which here represents a range of precipitous escarpment winding by Daignish to Armaddy Castle for a distance of about eight miles. The absence of this sedimentary group may arise from several causes, the chief of which is no doubt to be found in the large amount of débris from the cliffs of andesite, whereby the ground is obscured where the outcrop would be looked for. One mile W.N.W. of Melfort House, under the cliff marked on the map as Druim Barr na Coille, bands of sandstone were observed to be intercalated with the strata of andesite, which on the south are thrown down by a N.E. and S.W. fault. Some of these bands are of economic value. They may be presumed to lie between the lava-sheets, since if they were the basement beds they might be expected to be conglomerates, which are generally the lowest beds in the Lorne district.

In the *Summary* for 1899 certain fragmental rocks which occur about a mile and a half north-east from Kilmelfort Hotel were referred to as conglomerates of Lower Old Red Sandstone age, but belonging to a higher horizon than that of the Oban or basement conglomerate.* During the present season these rocks were again examined by MESSRS. PEACH, SYMES, and KYNASTON, who have come to the conclusion that they are to be regarded as of the nature of volcanic agglomerates rather than ordinary sediments. Dykes of porphyrite have been injected into them. The matrix between their blocks is often of a crystalline igneous material with flow-structure, showing that the blocks have been involved and carried forward in actual flowing molten rock. These masses may, therefore, be connected with the flow-breccias mentioned in the last report.† From the local character of the materials and the mode of occurrence of these sheets of breccia

* *Summary of Progress* for 1899, p. 97. † *Op. cit.*, p. 100.

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and agglomerate, it is probable that underneath this platform of volcanic débris one or more volcanic necks or vents may lie concealed. An actual neck which occurs a little to the south has already been described.* These necks and the platform of ejected matter in all probability belong to the later phases of the Lower Old Red Sandstone period of vulcanicity as manifested in Lorne. If this be the case, then, as the agglomerate rests immediately on the schist, this area must have escaped invasion by the earlier more basic lava-flows. Mr. R. G. Symes.

On the west side of the island of Luing several sills of felsite with blebs of quartz traverse the slates in the direction of their schistosity without affecting them as the basalt dykes do. Similar sills occur on the east side of Shuna and Torsay.

Lorne Volcanic Region.—In pushing the survey of Lorne further to the north and north-east, MR. KYNASTON has obtained results of great interest in regard to the history of the various igneous rocks associated with the Lower Old Red Sandstone of that part of Scotland. He has made a re-examination of the andesitic lavas and basement conglomerates between the main road leading to Glen Nant and the Pass of Brander. Beneath the lavas in this area there lies sometimes a conglomerate consisting of rounded pebbles of quartzite, andesite, and vein-quartz, and sometimes breccia, of angular fragments of the immediately underlying schists, such as black slate, limestone, phyllite, and epidiorite. As this basement-bed is traced northwards towards the Pass of Brander, it seems to undergo a gradual change, as if it had suffered a general induration. This alteration is especially noticeable at a distance of about half a mile from the Pass. The rock is not exposed, however, near enough to the granite to afford the means of deciding whether or not this appearance is due to contact metamorphism. Above the conglomerate, at from a half to a quarter of a mile from the Pass, certain strata appear with a banded or laminated structure, which in parts strongly resemble tuff, and show numerous small fragments of the underlying schists, though not resembling the typical tuffs, associated with the upper portion of the volcanic series. In their case also there is an appearance of induration. They are frequently full of greenish streaks and patches, from the presence of epidotic material. They may possibly be of sedimentary origin. The microscope does not bring out indications that can be regarded as conclusive of contact-action in them. Mr. Kynaston.

Above these banded beds come the normal pyroxene-andesites. They, too, present an indurated appearance, and are very refractory under the hammer. The microscope shows that they are augite-andesites of a basic variety, and that if they have suffered any contact-alteration it can only be slight. The rocks are so obscured by decomposition that accurate observations upon them are not easy. The abundance of small grains and granules of pyroxene seen in the ground mass [9031

* *Loc. cit.*

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Mr. Kynaston.

and 9032] seems unusual. Very possibly it may be that these rocks are still too far (about three-quarters of a mile) from the granite for the question to be definitely decided either in the field or with the microscope; for although the older rocks below the andesites, on the south side of the Pass of Brander, distinctly assume the characters of hornfels, it does not necessarily follow that decided contact-phenomena should also be found in the lavas—assuming these latter to be older than the granite. For, other things being equal, we should not expect contact-phenomena to be exhibited at as great a distance from the intrusive mass in the case of igneous rock as in that of rocks of sedimentary origin. However this may be, there seems to be a decided difference, though rather of a general than a particular nature, between the andesites and basement beds near the Pass of Brander and similar kinds of rock at a greater distance from it. In the case of the Black Mount area, to be afterwards described, where the contact-alteration of andesites can be clearly demonstrated, the phenomena specially characteristic of such alteration in these rocks is imperceptible at more than a quarter of a mile from the granite. So that, even if contact-action could be shown to be entirely absent from the Pass of Brander andesites, three-quarters of a mile from the granite, it could not be concluded that they are therefore later than the granite-intrusion.

One other point is, perhaps, deserving of notice, though it may possibly have no special significance in this connection. At about a quarter of a mile from the Pass of Brander, a band of rock, not more than four or five inches broad, traverses the andesites. It has a somewhat coarse appearance for the size of the intrusion, and might almost be taken for granite. Under the microscope, however [9028], there are seen to be two generations of crystallisation, the phenocrysts being so numerous as to render the presence of ground-mass almost inappreciable in a hand specimen. The rock is of an unusal type in this district, and consists of idiomorphic plagioclases, quartz, often showing crystal outline, augite, green hornblende more or less altered into chlorite, and some chloritised biotite, while interstitial felspar and quartz form the ground-mass. The two latter minerals occasionally form micropegmatite. The rock may be termed an augite-bearing microgranite. But its texture seems unusually coarse for so narrow a band, and there is no appreciable change of texture at its junction with the andesite, even under the microscope. It is not the usual type found in intrusive sills and dykes among the andesites; it resembles rather the more deep-seated type of intrusion met with in some of the porphyrites cutting the granites. But even in the granites an intrusion of such small size is usually of a compact texture. It suggests (like the phenomena of granite veins) that at the time of its intrusion the temperature of the surrounding rock was sufficiently high to allow of its cooling comparatively slowly. At the same time it is quite possible that conditions favourable to the formation of this type of intrusion in this particular area

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may have been brought about by other causes than those specially connected with the intrusion of a large granitic mass. Finally, although certain phenomena near the Pass of Brander seem to be distinctly suggestive of contact-alteration, they do not furnish conclusive evidence that the intrusion of the Ben Cruachan granite was later than the andesites of this area. Mr. Kynaston.

How far the evidence of the Blackmount volcanic series affects this question will be discussed further on. If these rocks, together with those of Glencoe and Ben Nevis, can be shown to be of the same age as the lavas west of the Pass of Brander, the question of the age of the Ben Cruachan granite will be settled.

Close to the lower end of Loch Avich an exposure of agglomerate-like rock, which forms a conspicuous feature above Craignamoraig, and was mapped by Mr. Hill in 1895, was revisited last year by Mr. Kynaston from Kilchrenan. The rock might at first be taken for the basement conglomerate, but closer inspection shows it to be rather of the nature of a coarse agglomerate. It may be followed for a hundred yards or so, close to the margin of the andesites. It forms a wall-like mass sometimes apparently against the andesites, and sometimes separated from them by the older schist. The fragments appear to have been derived entirely from the schists, vary considerably in size, and are almost invariably angular. Some parts consist of a fine-grained breccia in a reddish matrix, but more usually there is a confused assemblage of large blocks up to 6 feet in diameter, which consist of the coarse and medium-grained schistose felspathic grits and fine greenish grits and slaty beds of the immediate neighbourhood.

Some sections show what is apparently a gradual breaking up of the schists *in situ* into angular fragments, as though an explosive outburst had torn away portions from the sides of a fissure. Possibly this agglomerate may indicate an infilled fissure (analogous to a neck), which may mark the site of some of the minor discharges of an explosive character, associated with the volcanic activity of the district.

The Ben Cruachan Granite.—From his station near Loch Creran Mr. Kynaston continued the mapping of the marginal portion of the north-western extension of the Ben Cruachan granite from near Ben Bhreac in a north-easterly direction as far as the head of Allt Buidhe, below the south-western spur of Beinn Sguliaird. The granite belongs to the more acid type, rather than to the dioritic modification of Bonawe and other places, and quartz may be clearly recognised with the naked eye. The texture is fairly coarse, even at the actual contact with the schists. Great difficulty was experienced in mapping out the boundary line between the granite and the schists, owing to the complicated nature of the marginal area. Indeed, in some places the granite and the schistose rocks are so intermixed that no sharply marked boundary-line can be drawn between them.

From time to time in former Reports allusion has been made

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Mr. Kynaston.

to the complex character of the granite margin.* In the recently-mapped area, however, the margin of the Ben Cruachan granite shows these complexities to a greater extent and over a much greater area than has previously been observed. The contact zone consists of a network of sills, veins, bands, and tongue-like protrusions of granite, covering a belt of mountainous ground sometimes more than a mile broad The vein-like offshoots do not, as a rule, anastomose with one another, but tend to run in a roughly parallel direction, coinciding with the original planes of foliation in the schists, although irregular intrusions of granite, having no apparent relation to any planes of weakness, are not uncommon. The complication is such that a line can only with difficulty be drawn between schists (hornfels), crowded with granite-veins and sill-like bands, and granite crowded with strips and inclusions of schist of every size up to a mile or more in length. The contact-area constitutes a zone of sill-like injections of great complexity. Towards the interior of this "injection-zone"—*i.e.*, as we approach the main mass of the granite—the schists are frequently seen to be so impregnated with granitic material that it is impossible in a hand-specimen to distinguish the igneous portion from the material of sedimentary origin. The original finely-banded character of the schists doubtless largely assisted this impregnation *(injection lit par lit)*. The same structure has also been observed close to the contact with the main mass of the granite, in the banded calcareous series of the Pass of Brander, where both "injection lit par lit" and "superposition" (Michel Lévy) may be seen sometimes in the same specimen.† Possibly both types may also be represented in the present case. There does not seem to be any definite zone of impregnation, but it may occur almost anywhere in the immediate proximity of veins, sills, or larger masses of the granite. It will also depend upon the structural character of the schists.

Further, in many places the schists have been broken up, under the process of injection, and a breccia has been formed—occasionally at some distance from the main mass—consisting of a confused mingling of altered schistose fragments in a granitic matrix. The fragments in the breccia are angular, and usually sharply marked off from the matrix. Occasionally, however, the outline is not well defined, and appears indistinct with a lens, showing, as it were, a gradual transition from the included fragment into the matrix. Such fragments are usually crowded with flakes of secondary biotite in more or or less parallel layers, and are somewhat suggestive of the origin of certain ill-defined patches rich in biotite, occasionally seen in the granite. Occasionally the breccia assumes a coarse aspect, as is well seen to the west of Meall Garbh, the fragments measuring several feet in diameter. This structure was evidently

* See, for example, *Summary of Progress* for 1897, p. 89.

† *Summary of Progress* for 1898, pp. 84, 85.

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an accompaniment of the intrusion and injection, and involves both homogeneous rocks, such as quartzite, as well as the banded schists. Good examples of quartzite-breccia were noticed at the granite contact in Glen Etive.* Mr. Kynaston.

Thus, in the marginal area of the granite every state of injection may be found from sill-like protrusions of the main mass many yards in breadth, to injections of microscopic dimensions. And similarly the granite displays included portions of the schists, varying from masses more than a mile in length to minute fragments. Even the smallest granite veins are of the same texture as the larger masses.

An intrusion of a fine-grained biotite-granite, or possibly diorite, was noticed near the head of Glen Dubh. The veins of coarse granite appear to end off abruptly against it, so it is possibly of slightly later date. It resembles some of the Kilmelfort types.

The Granites of the Blackmount and Moor of Rannoch.—A considerable area of granitic rocks was mapped last year from Kingshouse, on the western margin of the Moor of Rannoch, and about four miles from the head of Glen Coe. These granites include four principal varieties, all of which have close petrological relationships, and are intimately associated with one another, so as to form integral portions of one enormous mass. They constitute the north-easterly extension of the granites of Ben Cruachan and Glen Etive; so that a continuous tract of granite stretches from the Ben Cruachan area to the Moor of Rannoch. A traverse from the Moor of Rannoch south-westwards to the higher hills of the Blackmount, presents the four main types of granite in the following order:—

1. Coarse foliated acid granite. (Moor of Rannoch type.)
2. Coarse acid porphyritic granite. (Marginal phase of Moor of Rannoch type—*c.f.*, the Glen Etive granite.)
3. Hornblende-granite and quartz-diorite.
4. Pinkish acid granite.

(2, 3, 4) Ben Cruachan types.

(1.) Moor of Rannoch type.—The normal type of rock which constitutes the floor of almost the entire eastern portion of the Moor of Rannoch is a coarse foliated hornblende-granitite. It is a pale grey rock, consisting of plagioclase, orthoclase, quartz, green and brown hornblende, biotite, sphene, and some iron ore. The foliation indicated in a hand-specimen by the arrangement of the hornblende and biotite is scarcely perceptible under the microscope [9128], though strain shadows may be seen in the quartz. The orthoclase is often moulded upon the quartz. The rock has close affinities with the Criffel type of granite. Occasionally it contains large white porphyritic felspars. Huge angular blocks of this granite, scattered in confusion among the moraine-mounds, lend a striking character to the somewhat desolate landscape of the Moor, while, here and there, the bare rock is exposed in rounded hummocks, or rises as small islands

* *Summary of Progress* for 1898, p. 81.

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Mr. Kynaston.

and headlands in the numerous lochans. As the exposures are traced eastward in the direction of Loch Laidon, the foliation gradually dies out and porphyritic felspars are no longer seen. In the area about the head of Loch Laidon, the rock is of thoroughly granitic structure and occasionally becomes slightly finer-grained. Exposures are more frequent and the rock tends to form more prominent features. Similarly, the foliation dies out westwards a short distance to the west of Kingshouse and at the foot of the eastern slopes of Craig Dubh and Meall a Bhuridh. The foliated type gradually passes into

(2) A coarse acid porphyritic granite. This is practically the same as the typical Moor of Rannoch rock, but without the foliation. It may be regarded as a marginal phase. It is precisely similar in composition, structure, and texture to the coarse porphyritic granite which constitutes the marginal phase of the Glen Etive granite. This latter has been described in former Reports as constituting a central core within, and of slightly later date than, the Ben Cruachan granite. In a similar way the Moor of Rannoch granite has the same relations to the Cruachan type of granite on the western side of the Moor, except that the latter type does not in this case surround the former. Thus, the coarse porphyritic type, forming the western margin of the Moor of Rannoch granite, is succeeded to the west by the more dioritic variety of the Ben Cruachan type. The one type passes into the other rather abruptly, and sometimes the coarse porphyritic rock sends out veins into the Cruachan type. A vein of this kind is well seen in the granite crags at the north-western end of Craig Dubh. The junction between the two rocks is not very sharp, but constitutes a passage from the one to the other, expressed by a transition-zone of about an inch in breadth. The two rocks are closely allied petrologically—in fact, they have the same petrological relationships to each other as the Cruachan and Glen Etive granites, the latter being rather the more acid of the two.

(3 and 4.) Hornblende-granite, diorite, and pinkish granitite, constituting the Ben Cruachan types. It is not necessary to enter into any detailed description of these rocks, as this has already been given.* The dioritic type, as has also been observed in the Ben Cruachan district, constitutes the more marginal modification, while the more acid type forms the more important bulk of the mass, including many of the higher hills of this part of the Blackmount, such as the Clachlet (3,602 feet), Aonach Mor (2,839 feet), etc. The diorite or hornblende-granite, when followed towards the inner part of the mass, appears to pass gradually and imperceptibly into the acid type. This latter, well seen in Corrie Ba and on the Clachlet, is identical with the rock forming the upper portion of Ben Cruachan. On the ridge of Craig Dubh the hornblende-granite is often much intermixed with the neighbouring quartzose and micaceous schists. These latter have frequently been broken up, and the fragments lie confusedly in a granitic matrix, which appears to flow round them.

* *Summary of Progress* for 1897, p. 85.

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The different types of granite here described, their relations to one another, and their behaviour in the field, indicate one closely connected whole. The mapping of the area from Ben Cruachan to the Moor of Rannoch clearly shows that the granites of Ben Cruachan, Glen Etive, and the Moor of Rannoch constitute a gigantic mass, which has assumed the form of a belt, about 10 miles broad (including the granite area on the west side of Loch Etive), with a general north-easterly and south-westerly trend. It is true that parts of this mass—the Glen Etive and Moor of Rannoch granites—appear to have been intruded at a slightly later date than the rest; but MR. KYNASTON believes that the interval between them was geologically insignificant, and that so far as this great mass has been mapped. it belongs in all its members to a single geological period. It is interesting to note in this connection that the trend of this belt of granitic rocks is similar to the general trend of the planes of foliation in the older schists. The numerous dykes and sills have had the same tendency impressed upon them, and the planes of foliation observed in part of the Moor of Rannoch granite follow similar lines. Mr. Kynaston.

The Volcanic Rocks of the Blackmount.—During the survey of the north-eastern portion of the Blackmount deer forest, a series of interesting volcanic rocks has been mapped, which doubtless represent an extension of the volcanic area of Glen Coe —an area which, owing to the rugged and inaccessible nature of the mountainous tract where the volcanic rocks occur, has hitherto received very little attention from the hands of geologists.* It has been supposed that these rocks constitute outliers of andesite lava-flows of probably Lower Old Red Sandstone age. That there are true lava-flows in the Glen Coe area may well be the case, but so far as the work has proceeded in the Blackmount, no rock has been met with which MR. KYNASTON could confidently assert to represent part of a true subaërial flow. The detailed mapping of the area has, up to the present, only included a very small portion of the volcanic series, but it has brought to light facts of great interest and significance.

The volcanic rocks occupy a tract of exceedingly mountainous ground on the south-east side of Glen Etive, and from about 3 to 5 miles south-east of the head of Glencoe. The volcanic tract apparently forms a roughly oval area, elongated in a north-westerly and south-easterly direction, and extends from Sron Creise, the conspicuous spur of the northern ridge of the Clach Leathad, south-eastward across the rugged Cam Glen to the sharp east-and-west ridge of Meall a Bhuridh, 3 miles S.S.W. of Kingshouse. The rocks which constitute this tract fall into three well-marked divisions:—(1) *felsites* (*rhyolites*), (2) *breccias* and *agglomerates*, (3) *hornblende-andesites*. This order represents that in which the rocks are frequently met with in proceeding from the margin into the central

* See Judd "On the Ancient Volcanoes of the Highlands." *Q.J.G.S.* vol. xxx., pp. 294, 295, and Teall, "British Petrography," pp. 287, 288.

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Mr. Kynaston.

portion of the volcanic area. The field-evidence leads to the conclusion that these rocks constitute a large and complex volcanic plug or neck, and that they represent the site in this area of one, or perhaps two, vents of eruption. These vents are now filled up with enormous masses of agglomerate and breccia, rhyolitic felsites, and andesites; and, further, the mapping has brought out what seems to be a definite arrangement of these materials within the vent. At the margin lies an outer zone of rhyolitic felsites, which may however be sometimes absent, or it may graduate into a moderately fine-grained felsitic-breccia (*i.e.*, a felsite, or rhyolite, charged with angular fragments). Within the felsite we find massive and usually coarse breccia and agglomerate, which may occupy the entire outer zone when the felsite is absent. The agglomerate encloses at least two central plugs of massive andesite. The andesites and rhyolitic rocks are, petrologically, typical lavas, but in the field they do not appear to constitute outpourings that have flowed out over the surface; there is no reason, however, that they should not represent, from their plug-like mode of occurrence, the subterranean portions of lava-flows which reached and were spread out over the surface. The behaviour of these rocks was found to be exceedingly puzzling, as no sign could be found of dip or separate flow or intercalated tuffs, or any of the well-known phenomena of the lavas of western Argyll, such as might give a clue to the structure of the ground, on the supposition of their being outliers. The rhyolites are seen to tower up in huge vertical walls and precipices split by numerous intersecting joint-planes, which sometimes give the rock a rudely columnar appearance. The scenery formed by these flinty-textured masses cannot fail to impress everyone who has seen the remarkable and precipitous eastern face of Stob Dearg, the highest point (3,345 feet) of the Buchaille Etive Mor. The andesites again form similar features on the south side of the Meall-a-Bhuridh ridge and above the Glas Choire north of the Clachlet, but they are more apt to crumble away and form long slopes of scree and talus. Where structure, otherwise than jointing, can be observed, it is invariably *vertical* or almost so. The fluxion-banding of the rhyolites, which is often well marked, is vertical. Different varieties of andesite succeed one another in vertical bands, sometimes, as on Meall a Bhuridh, with vertical flow-banding. Vesicular structure is rare or altogether absent. The rocks traverse alike elevated ridges and deep glens in a manner which cannot be reconciled with the idea of outliers. But a study of the junction sections between the finer breccias and felsites and the surrounding quartzites seems to afford perhaps the most conclusive test of the nature and mode of occurrence of these volcanic masses. On the north-eastern slopes of Meall a Bhuridh some excellent junctions or contact-sections are exposed, where the lowermost crags of felsite and breccia stand out above the quartzites. At first sight these volcanic crags might appear to be resting *upon* the quartzites, but a closer examination shows that the felsites and

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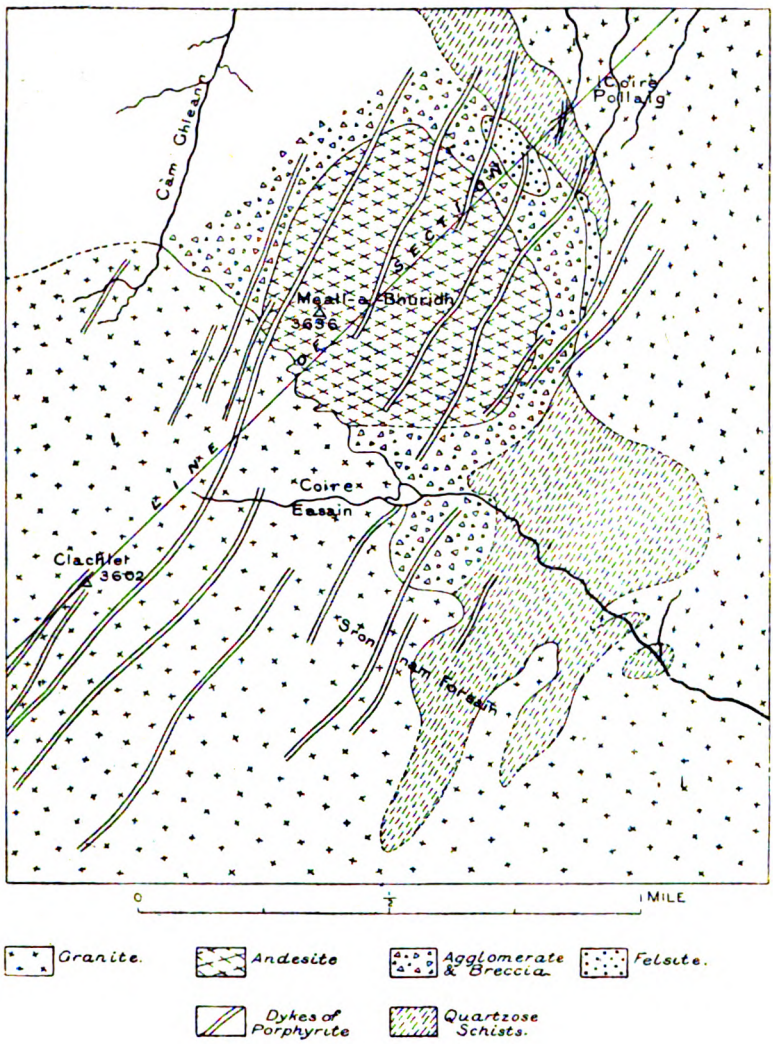

MAP AND SECTION OF CONTACT OF GRANITE AND VOLCANIC VENT, BLACKMOUNT, ARGYLLSHIRE.

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Mr. Kynaston.

felsitic breccias rest *vertically* against the quartzites and quartzose schists, the former being frequently crowded with quartzite and schistose fragments. The junction is like that of an intrusive rock, the volcanic rocks appearing to have been forced up through the schists. The felsite sometimes shows good flow-structure, which is vertical, at the contact. The foliation in the schists is here also vertical, but it is not normally so in this area. The felsite appears to graduate into the breccia by a gradual accretion of foreign fragments. Sometimes the schists are undisturbed, and the contact is remarkably clean and sharp, but often, again, they are extremely broken up, and indicate in a remarkable manner the shattering and rending force of the volcanic outbursts. In the former case the contact is usually with compact felsite, in the latter case with breccia.

In some cases the junction between the older rocks and the breccia, connected with the outer zone of the neck, is exceedingly complex. It may in these cases consist almost entirely of quartzite fragments, and it is difficult to separate it from the true quartzite. From normal apparently undisturbed quartzite we pass into shattered quartzite, and from this into quartzite-breccia, with a dark greyish, sometimes almost black, matrix, full of small quartz grains. This is well seen at the side of the burn in Coire-an-Easain, south of Meall a Bhuridh, where also veins and bands of the breccia pierce the quartzites in an intrusive manner.

The survey of the entire area of the neck is not yet completed, but the facts at present known from the mapping, and from traverses over the other part of the ground, show that the tract is probably of an elongated oval or elliptical form, the outer portions of which are occupied by felsites, breccias, and agglomerates, while the inner portion contains two plugs of andesite; one constituting the whole of the upper part of Meall a Bhuridh (3,636 feet), exposed to a vertical thickness of nearly 1,600 feet, and measuring over half-a-mile in diameter; the other being exposed for a distance of close upon a mile on the elevated ridge (3,600 feet) between Sron Creise and the Clach Leathad. These two plugs are separated mainly by agglomerate, though between the two there are evidences of one or two subordinate plugs of lava. Along its longer axis the entire neck measures at least two miles. To add to the complexity of these volcanic masses, a vast number of sills and dykes of porphyrite, with some of quartz-porphyry, have cut through them in a general north-easterly and south-westerly direction, and these appear to increase in frequency in the central plugs of andesite. Furthermore, the granite of the Clach Leathad, which, as above stated, is an extension of that of Ben Cruachan, has invaded the neck in its south-western portion, and intrusive contact-sections may clearly be seen between it and the andesites and breccias of Meall a Bhuridh on the one hand, and the andesites of the ridge north of the Clach Leathad on the other. The granite has been intruded into these rocks, and frequently veins them. The contacts in

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the field are clear and well-defined, and decided contact-alteration has been produced. This has been confirmed beyond all room for doubt by the study of a number of sections of both altered and unaltered rocks under the microscope. Mr. Kynaston.

With regard to the relation of the different kinds of rock in the neck to one another, the felsite or rhyolite, as already remarked, appears to graduate into the finer type of breccia, and one cannot draw any line between this material and the coarser breccias and agglomerates. There may, however, be some felsites which are intrusive in the agglomerates. No hard and fast line can be drawn between breccias consisting almost entirely of quartzite fragments and coarse agglomerates consisting mainly of fragments of felsite and andesite. In some places the breccia might be termed comparatively fine-grained, and is full of small fragments of quartzite and felsite, averaging half an inch in length or less, but more usually the main mass of the rock is a confused agglomeratic mixture of angular fragments of all sizes, consisting of quartzite, felsite, micaceous schist, with occasional pieces of andesite. The quartzite fragments are sometimes two yards or more in length. As we approach the andesite, the agglomerate becomes more and more andesitic, consisting mainly of andesite fragments, but not invariably so; sometimes, as on the south-east side of Meall a Bhuridh, the fragments become smaller and less abundant, until a kind of transition rock appears, which seems to be blended and interbanded in a peculiar manner with the true andesite. The appearance is sometimes that of a passage, and sometimes that of a vertical intrusive junction, on the part of the andesite. At the junction the andesite is often exceedingly rich in derived quartz grains and fragments of quartzite. On Meall a Bhuridh more or less vertical bands of slightly varying types of andesite succeed one another as the ridge is followed from east to west. These bands appear, like the porphyrite dykes, to have here a N.N.E. and S.S.W. trend. Sometimes a thin layer of brecciated andesite is seen between two bands. Along the summit of the ridge the banding due to flow is vertical; at the west end, above the granite contact, it seems to dip steeply eastwards into the hill.

On the north side of Glen Etive large masses of rhyolitic rocks breccias, and agglomerates form the Buchaille Etive Mor, and mark apparently another large neck. Stob Dearg, the highest peak, appears to consist mainly of masses of a rhyolitic nature from base to summit; but the mapping has not been commenced yet in detail on this side of the glen. A traverse has shown the existence of several varieties of rock of rhyolitic affinities, of a compact flint-like texture, varying in colour from almost black through shades of purple and brown to a brick-red, often with a most perfect flow-structure, and usually showing small felspar phenocrysts, with occasionally quartz in addition. The red felsites forming the summit (hence its name, Stob Dearg—the red peak) present a striking appearance, broken and splintered by the action of the frost, and strewn over the surface in count-

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Mr. Kynaston.

less sharp, angular fragments. Breccias and agglomerates are seen just below the summit, and throughout the greater portion of the big corrie on the south-west side.

Mr. Kynaston has made a study of the petrographical character of the Rhyolitic rocks, the Breccias and Agglomerates, and the Andesites. His results will appear in the Survey Memoirs. Space, however, may be found here for his account of the contact phenomena of this region, as these bear on the age of the granites.

The rocks that have been altered by the intrusion of the granite into the volcanic series comprise the andesites of the western and south-western slopes of Meall a Bhuridh, and of the ridge north of the Clach Leathad, with some of the finer-grained varieties of the breccias between them. Some of the rhyolitic rocks occur very near the granite at the east end of Meall a Bhuridh, but no marked signs of contact alteration have been observed in them. The alteration of the breccias has not yet been examined in detail. Some of the specimens examined were evidently complex rocks, consisting of a mixture of andesitic and more or less fragmental material rich in derived quartz. The fragments of quartzite in these rocks appear to be gradually losing their individuality; the sharp outline becomes indistinct, and under the microscope [9170] the fragments tend to become merged into the surrounding rock. The main mass of the section consists in part of a mosaic of quartz and felspar, throughout which are scattered numerous small biotite flakes, minute greenish grains (hornblende?), and magnetite, and in part of quartz grains in a fine brownish matrix. Other portions, again, break up into a mosaic of micropoikilitic felspar, in which the secondary minerals are embedded. Sometimes there is a marked parallel arrangement between the different materials, and sometimes the appearance of brecciation [9173]. In less altered specimens the andesitic portions retain their original structure [9172]. These rocks, then, are not true andesites, but mixtures of material of diverse origin, whose presence is perhaps rather to be expected at a main focus of volcanic activity.

In the *andesites* the commencing stages of alteration are seen at the west end of the Meall a Bhuridh ridge, and may be traced up to the granite contact. One of the most noticeable general features of these altered rocks is the invariable loss of the dark, almost velvety appearance of the unaltered fresh rock. The colour becomes pale grey and the rock loses its sharp angular fracture, presumably with the development of a more thoroughly holocrystalline structure. The brown hornblende, the first mineral to be attacked, is replaced by clusters of small biotite flakes, usually associated with aggregates of green hornblende and magnetite granules [9163, 9174]. At first the form of the original crystal is maintained, but it is completely lost in the later stages; frequently the replacing aggregate consists almost entirely of green hornblende, and, on the other hand, in the pyroxene-bearing varieties north of the Clach Leathad, the brown hornblende is replaced almost entirely by biotite, with a little

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magnetite. In the commencing stages portions of the original unaltered hornblende may be seen surrounded by a thick cluster of biotite flakes, the whole with the characteristic form of the hornblende crystal [9179]. The felspar phenocysts are usually marked by a peculiar cloudiness, but show a marked stability, and sometimes appear to maintain their individuality even at the actual contact [9169]. The microlites of the ground-mass become indistinct, and gradually the entire ground-mass becomes replaced by a clear granular mosaic [9171, 9174]. Sometimes a relatively coarse aggregate is seen of clear micropoikilitic felspar, in the more advanced stages [9176], while a profusion of small biotite flakes, often in aggregates, and frequently accompanied by green hornblende and granules of magnetite, lies scattered throughout. The green hornblende is sometimes in excess of the biotite [9177]. Grains of sphene occur at the actual contact [9176]. The pale greenish augite, when present, is replaced by a pale green hornblende, but shows far more stability than the phenocrysts of brown hornblende [9179]. At the contact the granite is fairly coarse and of an acid type. It sometimes sends small tongues into and encloses portions of the andesite [9169]. Mr. Kynaston.

It has now been conclusively shown that the great granite mass which extends from Ben Cruachan to Kingshouse is of later date than the plugging up of the great necks of the Blackmount area, and there can be no reason to doubt that these latter are an extension of the volcanic series of Glencoe. The Glencoe rocks have for some time been regarded as of Lower Old Red Sandstone age; the survey of the Blackmount area, although at an early stage, tends to support this view. It might perhaps be urged that no true augite- or enstatite-andesites, such as are so characteristic of the Lorne basin, have been found among the Blackmount series, and that the whole of this latter series has a more acid tendency. But it must be remembered that it is an exceedingly common and characteristic feature in many volcanic districts for the materials of necks and plugs to be more acid than the lava-flows which are associated with them, and we know also that in the upper part of the Lorne series there are acid rocks allied to rhyolite, sometimes associated, as in Glen Nant, with hornblende-andesites.* Further, the tuffs of Lorne, which belong also to a high horizon, indicate the blowing to pieces of acid rocks, and frequently contain fragments of typical hornblende-andesites. It would not be surprising, therefore, to find plugs of the same age containing hornblende-andesites and felsites, since such plugging up of vents of eruption must necessarily succeed the latest subaërial outpourings and represent the final phase of the eruptive activity of a volcanic focus. In the agglomerates near Kilmelfort, mapped by Messrs. Peach and Symes, Mr. Kynaston noticed many phenomena similar to those observed in the Blackmount. He has also recently collected evidence of the existence of a series of altered andesitic rocks on

* See *Summary of Progress* for 1897, p. 84.

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Mr. Kynaston.

the eastern side of the Ben Cruachan range, which in many respects show a remarkable resemblance to the altered andesites of Meall a Bhuridh and the Clach Leathad ridge above described, and have a similar mode of occurrence. If the evidence of these rocks is to be relied upon, this fact would help, as it were, to bridge over the gap between the Lorne basin and the Blackmount.

Sills and Dykes.—In the area of the Blackmount numerous sills and dykes traverse the older schistose rocks, the volcanic series, and the granites. They comprise some quartz-porphyries, a large assemblage of porphyrites, the small and more compact varieties of which are practically intrusive andesites, with an occasional diorite and camptonite. A good quartz-porphyry is seen cutting the felsites of Sron Creise. It shows crystals of orthoclase, plagioclase, quartz, and some chloritic pseudomorphs after biotite, in a cryptocrystalline matrix [9130]. The quartz often shows good crystal form, and only very slight magmatic corrosion. The porphyrites are especially abundant in the neighbourhood of the andesitic plugs. They resemble for the most part the porphyrite sills in the Ben Cruachan area. A sill of a very fresh and typical hornblende-porphyrite, seen at the top of Stob a Choire Odhair, shows under the microscope [9020] phenocrysts of clear plagioclase, often zoned and sometimes showing pericline twinning, fresh idiomorphic brown hornblende and biotite. Both the hornblende and biotite are occasionally enclosed in the felspar. Some pale green fibrous hornblende also occurs, which may possibly represent altered augite. Sphene, magnetite, and apatite are accessory. The ground-mass is microcrystalline, and consists of small plagioclases, small biotite flakes, with some interstitial quartz, and probably also some alkali felspar. The porphyrites invariably show a well-marked chilled edge, the marginal part being often almost black, and resembling an andesite, while the central portion may be of a brick-red colour. Specimens from the margin and centre of one of these sills were compared under the microscope. The central portion [9131] shows phenocrysts of hornblende, biotite, and plagioclase, in a ground-mass consisting mainly of smaller plagioclases and micropegmatite. Sphene and apatite are accessory. The margin of the same sill [9132] shows phenocrysts of the same minerals, but in a much fresher condition and with sharper crystal-outlines, in a brownish felsitic matrix, which under crossed nicols splits up into lighter and darker spots and patches, possibly representing a sub-microscopic stage in the development of the micropegmatite seen in the central portion. These sills evidently represent the dyke-phase of a hornblende-andesite magma. They resemble the hornblende-porphyrites of the Criffel area.

A rather unusual type of diorite is seen cutting the quartzites on the north side of Corrie Bà. It appears to consist [9133] mainly of plagioclase and hornblende. The former is for the most part idiomorphic, and the latter consists of two varieties—one reddish-brown and the other pale green. The brown horn-

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blende occurs as relatively large patches which frequently enclose small idiomorphic felspars in a poikilitic or ophitic manner. It is also frequently crowded with small opaque, rod-like inclusions, with a parallel arrangement. The green hornblende occurs in smaller crystals and grains, and occasionally appears to form a narrow border to portions of the brown hornblende and in crystalline continuity with it. Mr. Kynaston.

Reference may here be made to a *lamprophyre* sill that occurs among the quartzites on the hill slope above the Episcopal church in Glen Creran. The weathered face is seen to be thickly studded with quartzite fragments, and in places the rock is so full of these fragments as to become a breccia. The fragments are sometimes rounded, but more often angular. The margin of the sill is a mixture of breccia and shattered quartzite. Somewhat similar sills have been reported by Mr. Grant Wilson from Glen Orchy, and from Glen Suileag in the Loch Eil district.* The sill in Glen Creran only appears at the surface for about 100 yards, disappearing below the quartzites at either end. We are, perhaps, therefore, not far from its vertical limit, and possibly we may explain the abundance of fragments by supposing them to represent portions torn from the walls of the fissure at various levels, and carried onwards, floating on the lamprophyre magma, so that they would tend to accumulate towards the limit of its intrusion.

Carboniferous.

During the past year the areas of Carboniferous rocks which have been examined and mapped by the Geological Survey have lain in South Wales, North Staffordshire, and adjoining counties, and the Culm districts of Devonshire.

South Wales.†

Carboniferous Limestone.—This subdivision of the system has been mapped on the North Crop by Mr. Cantrill, and in Gower on the South Crop by Mr. Tiddeman. It not only expands vastly in its passage southwards under the coal-field, but changes so completely in the detailed sequence of strata that no correlation of the two tracts is possible except as regards the upper and lower members. On the other hand, the sections observed by Mr. Cantrill correspond almost in detail with those described in previous Reports along the North Crop further east, while Mr. Tiddeman is able to pick up in Gower some of the horizons with which he had become familiar in the neighbourhood of Bridgend. Further proof is thus afforded of the fact already made clear that the members of the Carboniferous system, though rapidly developing and changing character in a north to south direction, remain fairly uniform in an east to west direction. It may be assumed that the rocks were deposited Messrs. Strahan, Tiddeman, and Cantrill.

* *Summary of Progress* for 1897, p. 66.

† This section has been drawn up by Mr. Strahan.

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Messrs. Strahan, Tiddeman, and Cantrill.

along a shore running east and west, at no great distance north of the present limit of the Carboniferous area.

In the North Crop Mr. Cantrill recognises the following divisions of the Limestone series, in descending order:—

Rottenstone Shales	Shales with thin black and impure Limestones decalcified at the outcrop, and worked for rottenstone, and with two or more thin bands of radiolarian chert.
Main Limestone	Dark Limestone with nodules of Black chert, devoid of radiolaria. Light-coloured Oolite, 30 to 40 feet. Dark Limestone and Oolite.
Lower Limestone Shales.	Shales with thin Limestones.

The Lower Limestone Shales are about 15 feet thick at Careg-yr-Ogof, the most northerly prolongation of the Limestone. Further west, at the sources of the Clydach, they are probably twice that thickness, and may there be seen to pass down into yellow sandy shales and sandstone, and so into the Grey Grits. On the Cennen they are about 34 feet thick.

Somewhat more than half of the Main Limestone consists of a dark rock, much of which is minutely oolitic. A thin band of corals some few feet above its base, which was first noticed east of Glyn Tawe, persists as far as the mapping has proceeded. Upon the top of the dark limestone comes a soft, fine-grained sandstone of a light-grey or yellow tint which weathers in the pitted manner characteristic of calcareous sandstones. It has evidently been a very sandy limestone. Though only about 10 feet thick, it has been traced almost continuously from Glyn Tawe westwards for about 12 miles. The sandstone is succeeded upwards by the light oolite, which always forms a conspicuous horizon about the middle of the limestone-crags. To the south-east of Trapp it is about 30 or 40 feet thick. It passes upwards through darker oolite containing many grains of sand, into dark thin-bedded limestone with nodules of black chert.

The Rottenstone Shales are of exceptional interest on account of the discovery in them of bands of radiolarian chert, as hereafter described. The series is thin and everywhere obscured by the *débris* of the Millstone Grit, but the outcrop is marked by an almost continuous line of old workings for the rottenstone, a residue of the thin black limestones after decalcification. The result of a microscopic examination of the chert by Dr. Hinde is given below. Though radiolaria are not uncommon, sponge spicules predominate. The occurrence of these organisms suggests a deep-water origin, but the series is immediately overlain by the pebbly conglomerate which forms the base of the Millstone Grit. Wavellite occurs on the joint-faces of the harder bands.

In the south crop Mr. Tiddeman finds evidence of a considerable development of the Lower Limestone Shales, though there are but few sections. The hamlet of Southgate is built on a splintery olive-brown shale in which fragmentary fossils occur, and there is a probable inlier near the village of Parkhill. The

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varieties of limestone previously observed by MR. TIDDEMAN (*Summary of Progress* for 1899, pp. 111-112) persist in the ground recently surveyed. The pitted limestones of pseudo-brecciated type, which are noticed at Newton Nottage and Mumbles Head, have been found near Llefridd and further south at Oxwich, with intermediate exposures at Pwll-du Head and Bishopston. They keep to a definite horizon near the top of the Carboniferous Limestone, and obviously owe their breccia-like appearance to conditions of original deposition, and not to crushing, although dolomitisation has been at work subsequently. Where dolomitisation has not been set up, the chinks which meander through the rock may be better seen, and it is, then, obvious that they do not follow planes, as would be the case with jointing or fractures from crushing, but wander about like the lines in a puzzle. The component pieces have been subjected to some force acting round separate centres, as in the formation of nodules, and the several spheres of influence have become irregularly crowded together at the periphery, thus producing the curious fissures which bound them. These have in most parts been paths for dolomitic action, and so the centres stand out like angular and rounded fragments, and look at first sight like those of breccias or conglomerates. Messrs. Strahan, Tiddeman, and Cantrill

The Upper Limestone Shales, which made their first, or most easterly, appearance near Penwyllt, in the North Crop,* have now been definitely recognised in the South Crop in Gower. A cutting on the road from Clyne Common to Bishopston forms the only section known at present, though clay was formerly dug from the outcrop of the shales near Newton. East of Swansea the series is unknown. It would seem, therefore, that while in both the North and South Crop the Upper Limestone Shales make their appearance in a westward direction, they come in somewhat later on the south side, or, in other words, that the eastern margin of their area of deposition runs in a south-westerly direction.

So long ago as 1846 these Bishopston strata received the close attention of DE LA BECHE.† He not only measured a detailed section‡ through some 1,600 feet of the strata lying next above the massive Carboniferous Limestone, and sketched the distribution of the series, but instituted a careful comparison of the Gower sequence with that of North Devon. He pointed out that the Gower series generally resembles the strata which graduate down into the Pilton group, and made special reference to certain whitish, grey, and black shales, in thin beds, intermingled with white arenaceous and argillaceous layers, noticed by PROF. PHILLIPS at Coddon Hill. The siliceous bands in the Coddon Hill strata had long been known to contain wavellite in the joints, and DE LA BECHE, without laying much

* *Summary of Progress* for 1898, p. 112.

† Memoirs of the Geological Survey, vol. i., pp. 133-134.

‡ The section is believed by MR. TIDDEMAN to have been measured along a cut for a mill-race now disused and overgrown.

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Messrs. Strahan, Tiddeman, and Cantrill.

stress on the fact, regarded it as interesting that the same mineral occurred under supposed similar geological conditions in Gower. These Coddon Hill beds, which had hitherto been regarded as arenaceous and cherty sediments, were proved in 1895 by DR. G. J. HINDE and MR. HOWARD FOX,* to be rocks of organic origin, consisting, to a great extent, of radiolaria, and forming one of the largest deposits of such remains hitherto known. Under these circumstances it was recognised that the detection of radiolaria in South Wales would possess the greatest interest as being likely to confirm the comparison instituted by DE LA BECHE, and to assist in the extremely difficult co-relation of the strata on the two sides of the Bristol Channel. Accordingly search was made, and met with immediate success, both in the North and South Crops. Sufficient proof has been obtained that the Coddon Hill Series, the Gower Series, and the Rottenstone Beds are strictly correlative deposits.

As described by MR. TIDDEMAN, the road in which the section occurs, between Clyne Common and Bishopston, runs parallel to the top of the uppermost massive limestone for about 500 yards. The rock is oolitic but dolomitised in places, and dips at 50 or 60 deg. to the N.N.E. The strata cut through by the road are somewhat crumpled. They consist in their lower part of at least 30 feet of white and yellow clays. Above these lie about 15 feet of more distinctly bedded clays, hard and soft, with irregular thin seams of limestone and chert; they contain wavellite (a hydrous phosphate of alumina) in small discs of radiating crystals in the joints of the harder bands, and yield a characteristic Carboniferous Limestone fauna. The following specimens have been identified by MR. E. T. NEWTON and Dr. F. L. KITCHIN from the rottenstone below the radiolarian cherts—

Crinoid stem ossicles (mould); *Fenestella* sp.; Polyzoon; *Chonetes?*; *Orthis* sp.; *Productus* (fragment of small valve); *Rhynchonella?*; *Spirifera trigonalis?* Mart.; *Spirifera?*; *Spiriferina cf. cristata*, Schloth; *Cythere?*; *Griffithides* (fragment of head-shield); *Phillipsia?* (pygidium).

The cherts in this series are silicified limestones, and contain a large foraminifer (cf. *Nummulina pristina*, Brady), sponge-spicules (decomposed), fragments of echinoderm plates and *Dentalium?* At the top of this group some thin black cherts occur, which are distinguished by showing white streaks, more or less lenticular. The resemblance of these banded cherts to the radiolarian chert of Coddon Hill was obvious, and a typical specimen was collected by MR. WOODWARD during a visit to the spot with MR. STRAHAN and MR. TIDDEMAN, in order that it might be examined under the microscope. The specimen was pronounced by DR. HINDE to be a typical example of the Culm Radiolarian Chert, and to resemble very closely the Devonshire culm cherts.

A few days after this specimen was obtained the outcrop of the Rottenstone beds on the north side of the Coal Field was visited by MR. STRAHAN and MR. CANTRILL, and specimens of

* *Quart. Journ. Geol. Soc.*, vol. li., p. 609.

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banded chert, which had been noted by the latter, were collected at Careg Dwfan, there being reason to believe both from their appearance and stratigraphical position that they would correspond to those of Gower. Slices from the cherts of both districts were submitted to Dr. G. J. Hinde, to whose kindness we are indebted for the following report:— Messrs. Strahan, Tiddeman, and Cantrill.

"A. Carmarthenshire. [North side of Coal Field.] Nos. E 3306, 3309, 3311-3314 are of the same character—dark cherts with lighter decayed portions. They mainly consist of casts of detached sponge-spicules and casts of Radiolaria, both organisms very faintly shown. The Radiolaria are, for the most part, simple circular and oval forms, probably belonging to *Cenosphæra* and *Cenellipsis;* only the outlines bounded by matrix, as a rule, are now preserved; in some instances, however, perforations in a wall can be seen. Oval forms with radial spines are rare.

"The sponge-spicules are apparently minute simple acerates, but with these four-or six-rayed spicules of hexactinellid sponges are occasionally present. It is possible that some of the needle-like spicules may be the broken off radial spines of radiolaria. The greater portion of the chert is evidently a mass of minute spicules or spines of siliceous sponges, with possibly some radiolarian spines; with these are commingled some radiolarian casts, but they are, relatively, in smaller proportions than the spicules.

"B. Glamorganshire.—Nos. 3334, 3337-3341, Bishopston road-cutting, and Nos. 3328-3331 road from Newton to Clyne Common. [Collected by Mr. Tiddeman.] These are hard black cherts with even horizontal bands of lighter tints. They all show numerous circular and oval casts of Radiolaria as clear spaces in a dark matrix. The casts for the most part are without walls or structure, but in some there are distinct spokes, radiating from an inner central sphere. They belong to *Cenosphæra, Carposphæra* and *Cenellipsis.* In addition the rock contains three-rayed spicules of the radiolarian genus *Sphærozoum.* Sponge spicules, also as casts, some hexactinellid, are likewise present, but subordinate in number to the Radiolaria. The specimens are typical radiolarian cherts.

"The character of the rock, the mode of preservation of the radiolaria, and the forms themselves are very similar to what are found in the cherts with Radiolaria from the Lower Culm of Devon and Cornwall described by Hinde and Fox (*Quart. Journ. Geol. Soc.*, vol. li., 1895), and two of the Radiolaria showing structure, *Porodiscus* and *Carposphæra,* are identical species with those figured in the Culm chert (*op. cit.*, Pl. xxv., figs. 6, 7; Pl. xxvii., fig. 1). The *Sphærozoum* spicules (Pl. xxv., figs. 1*e*, 1*f*, 1*g*,), also correspond closely with those from the Culm. This, resemblance to forms from the Lower Culm chert is more strongly marked in the chert specimens from Gower; the Radiolaria from Carmarthenshire are, as a rule, distinctly smaller . . . . . and, as already mentioned, they occur in a rock in which sponge spicules predominate, whereas in the Glamorgan chert the prevailing facies is unmistakably Radiolarian."*

* From a letter by Dr. George J. Hinde, F.R.S., dated Dec. 18th, 1900.

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Continuing the examination of the series in an ascending direction, MR. TIDDEMAN finds that the clays give way to much chert, mostly black, and not banded, associated with hard cherty shale, the whole being only a few feet thick. These cherty strata in his opinion, mark the upward limit of the usual Carboniferous Limestone fauna; above them there occurs a thick mass of black or bluish ferruginous shales, all dipping at a high angle and occupying a belt of ground about 1,000 yards wide. It may be inferred that they are thick, and, in fact, DE LA BECHE'S section shows more than 1,590 feet above the cherty zone, but the mapping of the region is not sufficiently advanced to enable us say whether or not there is repetition. *Glyphioceras bilingue*, Salt. which is described and figured under the name of *Goniatites bilinguis* by SALTER,* occurs abundantly in some bands, and *Posidonomya* has been observed by MR. TIDDEMAN. The *Glyphioceras* is a common shell in the Millstone Grit shales of Yorkshire, Lancashire, and Derbyshire.

Millstone Grit.—As already mentioned, the summits of the Black Mountains are formed by the basal conglomerate of the Millstone Grit west of the point at which the hard conglomeratic beds at the top of the red sandstone subdivision of the Old Red series disappear. One of the finest exhibitions of the rock is furnished by the faulted promontory of Gareg-lâs, but westwards the conglomerate is disintegrated. At several points there is a notable absence of pebbles, and at Pen-rhiw-wen soft grit beds are dug for "silica-sand."

The breadth of outcrop presented by the grit west of the Neath and Llangadock road is maintained in spite of an increase of dip, owing to the influence of a well-marked roll which traverses the district between the Amman and the Cennen in a general E.N.E. direction. The ridge of Tair Carn marks an anticline, while the upper part of the valley of the Llwchwr follows a parallel syncline, by which the middle or shaly portion of the Millstone Grit is introduced. This belt of folding runs parallel to and about six miles north-west of the Cribarth disturbance. The sandstones and shales which constitute the upper part of the Millstone Grit form dip-slopes on the moorlands north of the Amman Valley and are well exposed in Cwm Garw.

Coal Measures.—The surveying of the Coal Measures during the past year has been carried on chiefly between the Tawe and Loughor Valleys, in an area of somewhat complex structure. In a general way the structural features resemble those of other parts of the coal-field, for the measures dip steeply along the South Crop, but rise gently towards the North Crop. The syncline thus produced, however, not only includes minor east and west folds, but is broken across by powerful faults ranging partly in the normal north-north-west direction, and partly

* *Mem. Geol. Surv.* Geology of the Country around Oldham, p. 60.

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in a direction somewhat east of north and approximately parallel to the Vale of Neath and Cribarth Disturbances.* Messrs. Strahan, Tiddeman, and Cantrill.

Of the minor east and west folds referred to, one runs from near Forest-fach westwards along the valley of the Afon Llan. It includes a syncline by which a trough of the Four-feet Seam has been thrown in, and a sharp but local anticline which has been proved to the north of the syncline, at Forest-fach. Another minor syncline runs under Rhyd-y-Pandy to Bryn Whilach, where it was found in working the Four-feet Seam. At that point it appears to turn westwards, and to pass under Tyle-du. There are therefore two distinct troughs of the Four-feet Seam and the measures above it, that is, of the uppermost existing measures of South Wales, which have been referred to in previous Reports as the Llantwit or Mynyddislwyn Measures. To the east of the Tawe, on the other hand, these minor folds have ceased to exist, and the main syncline of the Coal Field has lost its compound character.

The most conspicuous of the other structural features referred to are the north-north-westerly faults which succeed one another with monotonous regularity. Most of them are downthrows to the west, but the Pwll-mawr Fault is a downthrow to the east of 80 yards at the Colliery of that name, and of no less than 130 yards at the Pen-rhiw-felen Colliery. Two of the faults, moreover, have been proved to change the direction of downthrow. One of them known as the Cwm Pit Fault is a downthrow to the west of 44 yards, but about half a mile further north ceases to shift the strata. In the same line, however, a few yards farther on, a fault commences with a small downthrow to the east which increases to 22 yards at Llangyfelach. The second case is that of John Grey's Fault, which is a downthrow to the west, of 178 yards, north of Cefn Cadle. Near Mynydd Newydd Colliery the throw is almost *nil*, while south of the colliery a fault in the same line throws the strata down to the east.

The third type of disturbance recognised in the Swansea district is represented by two deep faulted hollows, the one concealed under the alluvium of the Tawe between Clydach and Morriston, and the other running near Melin Cadle between the workings near Forest-fach and those at Carngoch The first named has been, to a great extent, explored, and has been proved to run somewhat east of north; the other is in process of being proved, and so far as the evidence goes, must have much the same direction. While distinct from the north-north-westerly system, these disturbances do not link themselves on to the east and west folds which plicate the strata in Gower. If, therefore, as seems probable, they belong to the same system as the Vale of Neath and Cribarth Disturbances, they indicate that a distinction exists between these disturbances and the plications of Gower and the Vale of Glamorgan, of which the pre-triassic age is so beautifully shown in Barry and Sully Islands.

* Described in the *Summary of Progress* for 1898, pp. 117–119.

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Messrs. Strahan, Tiddeman, and Cantrill.

The seams which have yielded nearly all the coal worked near Swansea lie high in or above the Pennant series, the highest existent being those which have been let down in the deep faulted hollows of the Tawe Valley and Melin Cadle. The Four-feet seam (as explained in the *Summary of Progress* for 1899, pp. 120, 121) is believed to be the Llantwit No. 1 or Mynydd-islwyn Seam, and as in the more eastern part of the Coal Field, the measures above it are generally soft. Above the Five-feet seam, on the other hand, there is a thick strong sandstone, which makes its presence known by such bold features as the crest of the hill above Morriston. A still stronger rock above the Graigola or Six-feet Vein gives rise to a subsidiary ridge running parallel to and on the north side of the main Pennant escarpment, and forms also broad tracts of mountain-land along the north crop of that vein. The following table gives the distances proved around Swansea and forms a continuation of the table given in the Summary for 1899, p. 121.

Table of Distances in Yards between the Principal Seams near and West of Swansea.

	Gorseinon.	Carn Goch.	Mynydd Newydd.	Penrhiwfelen.	Pentre Pit and Borehole.	Calland's Pit.	Mansel and Graig.	Llansamlet.
Drews vein	–	–	–	–	–	–	–	–
Measures	–	–	–	–	–	–	–	165
Four-feet vein	–	–	–	–	–	–	–	–
Measures	118	115	–	–	–	–	–	118
Five-feet vein	–	–	–	–	–	–	–	–
Measures	–	–	–	–	–	–	–	–
Jenkin vein	133	–	141	139	–	–	–	118
Measures	–	–	–	–	44	55	52	–
Six-feet vein	–	–	–	–	–	–	–	–
Measures	22	–	12	13	18	16	13	20
Three-feet vein	–	–	–	–	–	–	–	–
Measures	–	–	–	–	38	38	49	44
Two-feet vein	–	–	–	–	–	–	–	–
Measures	–	–	–	–	200	–	202	–
Slatog vein	–	–	–	–	–	–	–	–
Measures	–	–	–	–	–	–	24	–
Curly vein	–	–	–	–	–	–	–	271
Measures		–	–	–	49	–	22	–
Bodwr vein	–	–	–	–	–	–	–	–
Measures	–	–	–	–	–	–	12	–
Hughes vein	–	–	–	–	–	–	–	–

All of the measurements given in this table were made in shafts sunk through nearly horizontal strata, with the exception of the Mansel and Graig Colleries, where they were taken by Mr. W. Morgan in a cross-measure drift through strata dipping at 32 deg. In the Pentre section the strata were proved from the Two-feet Vein downwards in a borehole, and the Llansamlet

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section is made up from various sources, no one shaft having proved the whole sequence. It will be seen that the thicknesses remain fairly constant from Swansea westwards, and that the seams are identifiable without difficulty. With respect to the correlation with the Neath trough,* one point may be added; a small seam, known as the Morris Vein east of the Tawe, and as the Jenkin Vein west of the river, occurs about 50 yards above the Graigola or Six-feet Vein, and may represent the Tyr Edmond Vein of Skewen, though it lies rather higher than might have been expected.† Messrs. Strahan, Tiddeman, and Cantrill.

The group of veins of which the Hughes is the most important, forms the base of the productive Swansea Coal Field, the seams lower in the Pennant being unimportant, while those at or below the base of that rock crop out under houses or in the foreshore, and are difficult of access. The Hughes group crops out along the north foot of the ridge of highly inclined Pennant which includes Kilvey and Town Hills and trends thence past Dunvant. The following estimate of the thickness of the grits below the Hughes group is approximate only, and may require modification as the examination of the ground proceeds :—

Descending Section near Swansea.

	Yards.
HUGHES (or WENALLT) VEIN—	
Measures, chiefly sandstone in the upper part as seen in the Cwm-bwrla Quarries - - - - - - -	267
CUCKOO or WAINWEN VEIN—	
Measures, chiefly sandstone as seen in the Baptistswell Quarries and on the summit of Kilvey Hill - -	217
DYVATTY VEIN, or supposed No. 2 RHONDDA—	
Measures, chiefly sandstone as seen in the Graig Quarries and on the southern face of Kilvey Hill, but with one or more thick beds of shale - - -	183
TOR MYNYDD VEIN—	

On comparing these estimates with those made in the Neath valley‡ we find a distance of 484 yards between the Hughes Vein and the supposed No. 2 Rhondda as compared with 420–440 yards, an increase in a southerly and westerly direction such as might have been expected.

The Cuckoo Vein, an unimportant seam in the middle of the main mass of Pennant Grit, is said to have been proved at Pen-y-graig. The Dyvatty Vein was formerly worked by a level near the Cattle Market and at the Workhouse. Six hundred

* *Summary of Progress* for 1899, p. 121.

† Opportunity may be taken here to correct two errors in the figures given in the *Summary of Progress* for 1899. On p. 120, the distance between the Wernffraith and Graigola Veins should be 254 yards and not 454 yards as printed. On p. 122 the throw of the Rhydding Fault at Cwm Clic should be given as about 580 yards instead of 340 yards.

‡ *Summary of Progress* for 1899, p. 118.

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yards west of the Workhouse there seems to be an upthrow to the west, for what appears to be the same vein has been worked in the quarries above Terrace Road, too high up for the crop proved at the Workhouse.

The measures below the Dyvatty Vein are partly shown in the Graig Quarries. Though including thick beds of shale, they consist chiefly of sandstone indistinguishable from the Pennant rock above the Dyvatty Vein. This rock presumably corresponds to the Llynfi or Tor Mynydd rock mapped by MR. TIDDEMAN further east. The Tor Mynydd Vein probably crops out below this rock, at the foot of the steep declivity along which Underhill Street is built. The lower Coal Series may be inferred to crop out under the gravel on which the lower part of Swansea is built and in the foreshore. A clue to its position may be furnished by the outcrop in Gower, in ground not yet surveyed.

The North Crop presents a marked difference to the South Crop in this part of the Coal-field in the Coal Measures, as in all the other members of the Carboniferous System. Not only do the measures decrease in thickness northwards, but the seams deteriorate or even dwindle away in that direction. Thus the Four-feet Seam, though it proved well as far north as Bryn Whilach, has not yet been definitely recognised at its north crop. The Five-feet Seam has been extensively worked around Morriston, but proved worthless near Clydach. It is worked at Carn Goch and proves well at Gorseinon, but is not known as a workable seam at its northern outcrop; under the name of the Greenway Seam it is workable at Skewen, but dwindles away under Mynydd Drumau. We can therefore define the northern limit of deposition of this seam in a workable form as a line drawn east and west through Mynydd Drumau, near Clydach, and thence westwards. The Six-feet, or Graigola Vein, on the other hand, is more persistent, and its northern crop may be traced step by step by an almost continuous line of old workings, though this seam also proved worthless under Banc Maes-tir-Mawr, apparently in consequence of a local "wash-out." The Three-feet and Two-feet veins, though of great value at Llansamlet and Landore, are worthless, though recognisable, in the Clydach Valley and on Mynydd y Gwair, and are unknown along the remainder of their north crop. The Hughes group again seems to be represented by one seam only at its northern rise in the Tawe Valley; at Graig-tre-banos there are two seams, a few yards apart, on this horizon, which are said, however, to be inferior and very sulphurous, while to the west of the Clydach Valley the group has not yet been recognised, unless it be represented by some thin coals in Cwm Cathan in ground not yet examined.

On the North Crop MR. CANTRILL commenced the examination of the lower coals and ironstones. They were formerly worked by patch-works at Brynamman, and they run thence along the south side of the Amman Valley. The next important coal above, known as the Red Vein, is separated from them by a considerable thickness of barren measures, and crops out at the

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foot of the high ground. It ranges from a little over 3 feet, at Gwaun-cae-gurwen, to 4 or 4½ feet at Cwm Gors and Cawdor collieries. Messrs. Strahan, Tiddeman, and Cantrill.

Above the Red Vein there are several unimportant seams generally overlain by sandstones resembling Pennant, and associated with bands of grey quartz-grit. These veins are worked to a small extent along the crops on Penlle'r-fedwen and Mynydd Gwrhyd. One of them is distinguished by the character of its roof, which is a coarse Pennant grit, containing ironstone-nodules, quartz-pebbles, and fragments of carbonised plants. It can be traced from the Bryn Llefrith Fault at Pen-rhiw-fawr south-westwards into Cwm-y-Gors, and so far as can be judged, occurs at about the same horizon as the Ynys-arwed Vein of the district east of the fault. The occurrence of a conglomeratic roof has been referred to as a characteristic of the Ynys-arwed Vein,* and it has also been pointed out that that vein represents the No. 2 Rhondda Seam. We are able, therefore, with some probability, to identify in the North Crop the equivalent of the Dyvatty Vein of the South Crop. There are indications, however, that both on the north and south sides of the coal-field this vein is becoming impersistent.

The rapidity of the change from bituminous coal to anthracite constitutes a most important feature in the seams of this part of the Coal-field. On the South Crop all are bituminous. Towards the centre of the field the uppermost seams still maintain a bituminous character, but the Six-feet and those below it have passed into the condition of steam-coals; and so rapidly that coal of a totally different quality may be obtained from the same vein in the workings of the same colliery. In the North Crop all the veins are anthracitic. Though the veins all become less bituminous northwards, the deeper veins are the first to change, so that in any one sinking the higher coals are always more bituminous then those at a depth.

No connection appears to exist between the anthracitisation and the structure of the ground; nor, on the other hand, is there evidence of the anthracitic region having been more deeply buried than the bituminous; on the contrary, the measures are far thicker along the bituminous South Crop than in the anthracitic North Crop. The phenomena point rather to the anthracitisation being a form of regional metamorphism.

Faults and Disturbances.—(1.) *North Crop.*—Of the numerous faults traced by Mr. Cantrill in the Lower Carboniferous Rocks of the North Crop one only has been found to extend southwards through the Coal Field—namely, that which is known in various parts of its course as the Cwm Llynfell, Bryn Llefrith, or Rhydding Fault.†

The Twrch Fechan Fault throws the middle shales of the Millstone Grit against the Basement Conglomerate on Llorfa, and forms the eastern boundary of the Millstone Grit of

* *Summary of Progress* for 1899, . 117. † *Ibid.*, pp. 122, 123.

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Messrs. Strahan, Tiddeman, and Cantrill.

Gareglâs for about a mile, after which it breaks up and ceases to be recognisable in the Old Red Sandstone. It has a downthrow to the west.

A fault, skirting the western side of the Twrch Valley throws Millstone Grit against limestone, and forms the western boundary of Gareg-lâs. Its downthrow is to the east.

The Cwm Llynfell, or Bryn Llefrith Fault runs along the eastern side of Mynydd Gwrhyd, throwing down the Pennant rocks of that hill on the west against the Red Vein on the east. At Cwm Llynfell its throw has been calculated on the following evidence. A shaft, commencing almost on a level with the crop of the vein, but on the opposite side of the fault, proved the Little Vein at twenty yards depth. The true distance between the Red and Little Veins is about 210 yards, which indicates that the throw of the fault is about 180 or 190 yards, rather less than was stated in the *Summary of Progress* for 1899, p. 117. The fault then skirts the western side of Gareg-lŵyd, where it throws the middle shales against the Basement Conglomerate of the Millstone Grit, and crosses the escarpment at Pen-rhiw-wen, with a throw exceeding 100 yards. In the Old Red Sandstone its course is obscure. Its downthrow is to the west.

A fault with a throw of only twelve yards in the lower veins at Brynamman crosses the Black Mountains to Nant Oesglyn. Its throw in the limestone appears to exceed 200 yards. It has a downthrow to the west.

A fault commencing in the Pedol Valley crosses the ridge of Tair Carn and dislocates the base of the limestone at Blaen Cennen. Downthrow to the east.

(2.) *In the Coal Field.*—Allusion has been made to the fact that the disturbances near Swansea fall into three groups—namely, the great synclinal and anticlinal folds, which run approximately east and west, and which are of pre-Triassic age; the north-north-west system of normal faults, which are believed to be, in part at least, of a much later age; and, thirdly, some deep-faulted troughs, which nearly agree in direction with the Vale of Neath and Cribarth Disturbances,* and of which the age is doubtful.

The east and west folds are exemplified by the broad compound syncline previously described as throwing in two fields of the Four-feet Vein between the Tawe and the Loughor; by the steep upturn of the measures of the South Crop; and by the sharp plications of the limestone of Gower.

The north-north-westerly system includes the following in consecutive order from east to west:—

The Gardener's Fault was traced as far north as Glais in the *Summary of Progress* for 1899, p. 123. It then seems to make a slight bend to the west in crossing the Tawe Valley, as was the case with the Dyffryn and Rhydding Faults, and to run between tracts of the Hughes' Seam at Craig-tre-banos and of the Graigola Seam of Cathelyd. Though it has not been reached in the work-

* *Summary of Progress* for 1898, pp. 116–119.

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Messrs. Strahan, Tiddeman, and Cantrill.

ings of either, the evidence at the surface points to its running a few yards west of Gellionen Farmhouse. Thence it presumably follows a hollow leading by Allt-y-Fanog, and skirts the western slopes of Carn Llecharth, where the form of the ground and lines of springs suggest a line of fault. It is evidently dying out northwards; its downthrow is to the west.

The Bethel Fault, which was believed to have been reached in the southern workings from the Garth Pit, is probably continuous with one of 60 yards throw proved at Bwllfa. The same line of dislocation continues by Fagwyr and along the western side of Mynydd-y-Gwair, where its shift of the outcrop of the Graigola Vein is recognisable, though small; downthrow west.

A fault on the west side of Mynydd Gelli-Wastad has been proved to have a throw of more than 55 yards. It runs under Glyn-collen, and is nearly in the line of the Six Pit Fault; downthrow west.

Several faults with throws ranging from 4 to more than 30 yards have been proved in the Six-feet (Graigola) workings near Rhos Fawr. All these have downthrows to the west.

A fault runs under Pentre Poeth and Cwm-rhyd-y-cwrw and is believed to continue thence by Maes-gwernen to the old Maes-tir-mawr shaft, where it divides, one branch running along the valley to Daren Fawr, while the other ranges across the mountain to near Rhyd-y-gelli-fawr. At Pentre Poeth this fault has been encountered in the Four-feet Vein, which lies at a shallow depth on its eastern side; on its western side this vein has been found in one place only, namely, in an exploration from the Pen-rhiw-felen Colliery, although trials have been made for it in other places; downthrow to the west.

The Maes-y-gelynen Fault is a continuation of the Pwll-mawr Fault.* It has been encountered in the Six-feet and Three-feet workings under Morriston, and was proved in the exploration at the Pen-rhiw-felen Colliery just referred to. A drift was carried through the fault from the Five-feet workings, and a borehole was put down, which proved the Four-feet Seam with the Two-feet† below it, at a depth of 9 yards. The throw of the fault is, therefore, about 130 yards, as compared with 80 yards at Pwll-mawr. Its course northwards is wholly unknown. It has a downthrow to the east.

The Cwm Pit Fault has already been noticed. It has a downthrow to the west, which changes northwards into a downthrow to the east.

The Cae Parc Fault has a throw of 22 yards near Tre-boeth, but dies out a mile to the north. Downthrow east.

John Grey's Fault has been mentioned previously as an example of a change of throw. That it is a downthrow to the east, south of Mynydd Newydd Colliery, was proved in a drift

* *Summary of Progress* for 1899, p. 124.

† Not the Two-feet Vein of Llansamlet, but a vein lying 4 or 5 yards below the Four-feet.

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from Pentre, which passed from the Six-feet Vein on the east side into measures below the Two-feet Vein on the west side; at the Colliery its throw is very small, while 84 chains northwards it has a downthrow to the west, of 178 yards.

The Pwll-yr-hywaid Fault has been met in the Five- and Six-feet workings from Mynydd Newydd, but not crossed. If, as there is some reason to believe, the Four-feet Vein is near the surface on the west side of the fault, the throw would not be large, but explorations are now proceeding; downthrow east.

The Penlle'r-brain Fault was proved in the Five-feet workings from Worcester Colliery to exceed 80 yards, and is supposed to be about 220 yards. A trial-pit near Kent on the west side of the fault was sunk 150 yards without proving the Four-feet Vein, although, as already mentioned, that vein may be near the surface on the east side of the fault. Further to the south-east the fault was proved in old workings in the Six-, Three-, and Two-feet Veins, but to the north-west its course is still unknown. So far the evidence points to its dying out rapidly, for though its throw is large as far as Cadle, it seems scarcely to shift the strata near Bryn-rhos. Its downthrow is to the west.

The next fault to be described has been proved in the Six-feet and Five-feet workings from Gorseinon and Carn-gôch Collieries to have a downthrow of 67 yards to the west. It runs along the foot of the Bryn-Dafydd hill to the west of the Pen-y-cwàr, and though its exact position under the alluvial meadows of Bach-y-gwreiddyn is unknown, its course by Allt-y-graban-fawr, the Bolgoed quarries, and thence across the Dulais, is clearly marked by an almost continuous bank of sandstone on its eastern or upthrow side. Nearly south of Bryn-Dafydd the fault has been proved to take a turn to the south-east, as though it were tending to run into the Penlle'r-brain Fault, but the ground between Bryn-Dafydd and Cadle shows evidence of a strong disturbance, as described below, and its structure has not yet been mastered in detail; downthrow to the west. Much assistance in the determination of this and other faults near Swansea, was given by Mr. THOMAS RICHARDS.

The third type of disturbance referred to is illustrated by two cases:—

The Tir Canol Fault is the name given to a deep faulted syncline, which runs under the alluvial flat of the Tawe from near Morriston to Clydach. The Four-feet Seam, which crops out a few yards north of the Marsh Pit, is about 18 yards deep at the Herring Pit (near Wychtree Bridge), and about the same depth at Tir Canol Pit. It crops out again near Carn-felin-fach, at the old Ynys-forgan slope, and presumably would be found cropping under the gravel near Garth Farm. These localities mark the southern and western margins of a deep trough, for the vein was worked at about 200 yards depth under Upper Forest Works; it dipped steeply down to S.E. towards the river at Ynys-forgan and Ynys-penllwch, and lay at a depth of 204 yards at Garth Pit. The trough thus defined follows the western edge of the alluvial flat pretty closely, and runs about N. 40° E

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A strong south-easterly dip is apparently the main factor in defining this edge, but it was found in working the Four-feet Vein that the high dip was accompanied by a series of step-faults down to the south-east; the name of Tir Canol Fault thus came to be applied to the disturbed belt, and it was credited with a throw of more than 200 yards. The sharp anticline which traverses Mynydd Gelli-Wastad, and the Cathelyd syncline north of it, seems to be part of the Tir Canol Disturbance; downthrow south-east. Messrs. Strahan, Tiddeman, and Cantrill.

A powerful disturbance, apparently of the same character, is believed to run from the neighbourhood of Cadle in a north-north-easterly direction. The examination of the ground is not yet completed, but the facts are as follows. The Five-feet seam has been worked north-westwards from Mynydd-Newydd to the Pwll-yr-hwyaid Fault, where it lies at a depth of about 122 yards. The dip being to the north-west, the Four-feet Vein should "take ground" at this spot, and no doubt does so under the swampy land between Blaen-y-maes and Glyn-siling. The Pwll-yr-hwyaid Fault being a downthrow to the east, the Four-feet Vein would come in somewhat further on its west side, and, as a matter of fact, there are some old levels north-east of Melin Cadle in a seam which is said to be 2 feet 6 inches thick, and which may be the Four-feet Vein. Further to the north at Tir-dwncyn the Cefn-gyfelach Company have worked the Five-feet Vein up to the John Grey's Fault, and have found reason to conclude that the Four-feet seam will lie at a depth of 40 yards, near Tir-dwncyn, where they have commenced sinking. North of this point we enter a tract deeply overspread with gravel and Boulder Clay, the bottom of which has not been reached. All along this east side of the Llan Valley the dip is in a general north-west direction, and it might be anticipated that the Four-feet Vein would be present under the valley and to the west of it.

On the west side of the River Llan a broad plateau of sandstone extends from Bryn-Dafydd to Melin Llan, the outcropping edge forming a bold and almost continuous escarpment. The Five- and Six-feet Veins are being worked below this sandstone, and it can be easily proved by a consideration of their depth that the rock lies immediately below the Four-feet seam. Accordingly, at Melin Llan, where the upper surface of the sandstone comes down to the river, we find resting upon it two somewhat inferior seams, which are no doubt the Four-Feet and a rider. These crops run down by Gorseinon Common to the Pen-y-cwâr Fault, to the west of which both have been proved and the rider has been worked. In addition to this a very small tract of the Four-Feet seam has been faulted in, 500 yards north-west of Bryn-Dafydd, the coal lying here again close on top of the sandstone. There is, therefore, no doubt that the Four-Feet Vein lies at a greatly higher level on the north-west than on the south-east side of the Llan Valley.

The difference in level, in view of the fact that the dip is uniformly north-westwards, cannot be accounted for by a roll,

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but must be due to a fault. On attempting to locate the fault precisely we are met with the difficulty that the ground is much obscured by drift and swamp, but there is sufficient evidence to show that it must run in a direction somewhat east of north. It must pass between the Kent Pit at Cadle and the Five-Feet workings of Carn-gôch. It was not reached in the Five-Feet workings from Mynydd-newydd, nor on the other side does it intersect the edge of the sandstone plateau along the drive to Penllergare. It must be to the west of some small riders which crop out near Glyn-siling (if, as seems likely, these are the riders of the Four-Feet seam), but it must lie to the east of a quarry in the sandstone 500 yards west of Cil-fŵnwr. Lastly, it must run to the east of Tredegar-fawr, for the Melin Llan Veins can be traced continuously up the sides of the Llan Valley to that farm. Piecing this evidence together, we may conclude that it passes somewhat west of Pont Cadle, under the Lake, giving rise to a strong issue of chalybeate water in the bank of the river 400 yards above the lake; that it runs thence to Tir-ffordd along a line where solid sandstone ground gives place suddenly to deep gravel, and that it passes east of Tredegar under the alluvial flats and drift-covered ground to the neighbourhood of Fforest-newydd. Further north, in the crop of the Graigola Vein, no sign is found of its existence.

North Staffordshire.

The resurvey of the North Staffordshire coalfield and surrounding ground has been continued during the past year by Messrs. Gibson, Pocock, and Wedd, under the superintendence of Mr. Fox Strangways. Mr. Gibson has commenced the survey of the Carboniferous, Triassic, and superficial deposits near Market Drayton; Messrs. Pocock and Wedd have been engaged in the survey of the same rocks round Macclesfield, Biddulph, and Congleton. A considerable time was taken up by Messrs. Gibson and Wedd in completing the collection of mining information relating to the Pottery coalfield. This has been a somewhat laborious task, owing to the number of collieries to be visited and to the complicated system of faulting and folding affecting the Coal-measures. In this work the Geological Survey has to thank the colliery managers, mining engineers, and surveyors for their courtesy in allowing access to plans, and for placing at our disposal their knowledge obtained in underground workings. The Map (Sheet 123, New Series) containing the major portion of the coalfield will be published during the year, and it is hoped that a Memoir, descriptive and explanatory of the map, together with a sheet of Vertical Sections, illustrating the character and thickness of the Coal-measures, will shortly follow the map.

Mr. Gibson.

The more important results obtained during the resurvey of the coalfield have been given in former Summaries. In that for 1899 it was stated that the subdivisions of the higher Coal-measures in North Staffordshire were found in the bore-hole at

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Thurgarton, near Nottingham, underlying the Magnesian Lime- Mr. Gibson.
stone series. With the object of ascertaining the distribution of these deposits over the Midlands, Mr. Gibson visited and examined the typical sections of the higher Coal-measures in Denbighshire and South Staffordshire. In the sections visible on the banks of the Ceriog and Dee, between Chirk and Wynnstay, he recognises the same sequence of red and grey rocks which succeed the productive Coal-measures in North Staffordshire. The "Etruria marls" are well shown in the banks of the Ceriog, between Chirk and Coed yr Allt. In Pentre-isaf ravine two bands of entomostracan limestone, containing *Carbonia*, occur near the base and middle of the marls. The lowest band, about 1 ft. 2 in. thick, is a light grey, fine-grained, earthy limestone, in which entomostraca and *Spirorbis* are sparsely distributed.* The higher band is a dark grey crystalline limestone containing entomostraca. The beds of green and greenish yellow grits, so characteristic of the Etruria marls in North Staffordshire and at Thurgarton, crop out on the banks of the Dee and Ceriog to the east of Chirk. It is noteworthy that the included fragments are larger and more angular than in North Staffordshire, and include fragments and chips of Silurian rocks derived from the neighbouring Denbighshire Hills. In Glyn Morlas, a tributary of the Ceriog, the purple mottled marls pass up into grey sandstones and shales containing, at Ifton Heath Colliery, four thin seams of coal. Similar sandstones and shales form the steep escarpment in Coed yr allt Wood, and are said by Mr. Davies† to include nodules and bands of calcareous rock. At the junction of the red and grey series in Glyn Morlas a thin band of limestone is developed containing *Carbonia* and *Anthracomya calcifera*, the latter being a small fossil distinctive of the limestone at the base of the "Newcastle series."‡ This grey set of rocks graduates upwards into lavender-coloured sandstones and marls identical in character with the "Keele Series," succeeding the "Newcastle-under-Lyme series" of the Pottery coalfield.

The same upward succession of red marls with green rocks followed by grey sandstones and shales, with an entomostracan limestone at the base, and succeeded by lavender-coloured sandstones and marls, can be seen near Ruabon and Wrexham, where the lower marls are largely used, as in Staffordshire, in the manufacture of bricks and drain-pipes. Near Wrexham the upper red marls (Keele Series) make good terra cotta ware, but they have not yet been put to this use in Staffordshire, though they will possibly be tried near Silverdale. The stratigraphical succession in Denbighshire and North Staffordshire is thus so nearly identical that there seems no doubt that the same conditions were prevalent in both districts at the close of the Carboniferous

* See Mr. D. C. Davies, *Quart. Journ. Geol. Soc.*, vol. xxxiii., p. 10. (1877.)

† *Op. cit.*

‡ *Summary of Progress*, 1899, p. 110.

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Mr. Gibson. period. That these coalfields are connected underneath the Triassic deposits of the Cheshire plain is evident.

A closely similar succession can be made out on the northern flanks of the Clent Hills between St. Kenelms and Old Hill. Some years ago MR. GIBSON mapped portions of this ground in connection with the field-class at the University, Birmingham. During his leave of absence last Christmas he revisited the sections between Old Hill and St. Kenelms, and found the red marls at Old Hill, used in the manufacture of the famous South Staffordshire blue bricks, to be identical in lithological character with the Etruria and Ruabon marls, and to contain the characteristic bands of green and greenish yellow grits and breccias. The latter are frequently very coarse and angular, containing numerous fragments derived from the neighbouring Cambrian and pre-Cambrian rocks of the Lickey Hills.

It is a point of considerable interest, scientific and commercial, that in Denbighshire and South Staffordshire, where the Coal-measures are close to or abut against the pre-Carboniferous rocks, the green grits and breccias contain large angular fragments of these rocks, whereas at Thurgarton and in North Staffordshire the green grits are much finer, and contain only small rounded fragments of older rocks.

The Old Hill marls are succeeded by the Halesowen sandstone group, a series of grey sandstones and shales, with thin coal-seams. Thin bands and nodules of earthy limestone (peldon) are developed throughout the series, but do not appear to contain any organisms. Similar bands of "peldon" are recorded from many bore-holes and shaft-sections sunk through the red Triassic rocks to the Coal-measures outside the South Staffordshire coalfield. A bed of grey limestone at the junction of the Old Hill marls with the Halesowen group yielded, near Halesowen, a few entomostraca. The Halesowen group is succeeded by a thin series of red, grey and olive-coloured shales and sandstones, with a band of *Spirorbis*-limestone and a few thin coals.* These are apparently represented in North Staffordshire by the grey measures in the Trentham boring at a depth of between 551 feet and 575 feet. They are followed in South Staffordshire by the lavender-coloured sandstones and marls of Hunnington, which are indistinguishable in lithological characters, from the Keele sandstones and marls. With the exception, therefore, of the thin limestone with *Spirorbis* at the top of the Halesowen group, the succession in South Staffordshire is identical with that in North Staffordshire. The wonderful similarity, even in details, in the character of the higher Coal-measures throughout the Midlands, no doubt indicates that the same conditions prevailed towards the close of the Carboniferous period, over an area extending from Nottingham to Denbighshire, and from Lancashire to the Lickey and Clent Hills.

It remains to be ascertained whether the so-called "Upper

* PROF. LAPWORTH, Proc. Geol. Assoc., 1898, p. 366.

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Coal-measures" of Coalbrookdale and the Forest of Wyre and Malvern Hills correspond with the higher measures of the other Midland coalfields. In North Staffordshire there is no break in the stratigraphical series from the lowest workable seam (Winpenny) to the highest measures (Keele series), whereas in the Coalbrookdale and Malvern areas a very marked discordance is said to divide the Upper and Middle measures. MR. GIBSON has been led to believe that over a large part of the Midlands no great break occurs, but only local irregularities and overlap, and that when a borehole fails to prove the productive measures below the higher measures, it will probably be found that the former have been cut out entirely or in part by one of those powerful faults from which none of the Midland coalfields are free. Mr. Gibson.

To the south-east of Market Drayton the same geologist has commenced the examination of the red rocks which have been considered to belong to the Permian system. They consist of irregularly-bedded red sandstones and red marls, admirably shown, as noted by PROF. HULL, in the long canal cutting between Tyrley Lock and Cheswardine. They are arranged in an anticline, surrounded on all sides by rocks of Triassic age. As they have yielded no fossils their age is doubtful. They bear considerable resemblance, however, to the higher portions of the Keele series as developed at Mucklestone and Moddershall. In a coppice near Chipnall wood a shallow shaft is said to have passed through a coal lying in these red rocks.

Mention was made in the *Summary of Progress* for 1899, p. 108, of the occurrence of an ironstone overlying the Chalky Mine Ironstone of Clanway Colliery, Tunstall, and an analysis of the raw stone by MR. W. JACKSON, A.R.C.S., was then given. A further analysis has been made by DR. W. POLLARD of the calcined stone obtained from samples taken from several heaps of burnt ore, and is here inserted:—

Analysis of Calcined Iron Ore from Clanway Colliery, Tunstall. Seam overlying the "Chalky Mine."

SiO_2	22·75	
Al_2O_3	10·96	
Fe_2O_3	39·80	Total amount of iron 41·32 %
FeO	17·31	
MnO	1·70	
CuO	Trace	
(MCo)O	·07	
BaO	·06	
CaO	2·98	
MgO	3·80	
P_2O_5	·75	
S	·07	
H_2O	·12	
	100·37	

The amount of silica is higher than in any of the ores used in the district, and is only approached by the "Gubbin," with 14·53

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Mr. Gibson.

per cent. (J. HOMER, *Proc. Iron and Steel Inst.*, Sept. 7th, 1875, p. 562).

In the neighbourhood of Macclesfield MR. POCOCK, besides revising the subdivisions of Millstone-grit made by PROFESSOR GREEN, has traced the boundaries of similar sandstones in the Coal-measures as well as of the thin sandstones and quartzites in the grit and shale group below the Millstone-grit series. The number of these grit bands and the broken condition of the strata has somewhat impeded the progress of mapping. The following succession of strata has been ascertained, with approximate estimate of the thickness of the different members:—

1. Kerridge sandstone, 150 feet.
2. Measures with coal seams, 200 feet.
3. Millstone grits (four beds with shale partings), 550 feet.
4. Shales, } 400 or 500 feet.
5. Shale grit, }
6. Shales with earthy limestone and marine band, } base not seen.
7. Yoredale sandstones (Crowstones), }

In this table Nos. 6 and 7 correspond with the Yoredale division, as determined on the eastern side of the Pennine range. The sandstones and crowstones are hard splintery sandstones or quartzites, which rise from beneath the shales with a steep dip and form a prominent group of hills due south of Macclesfield, of which the highest, Croker Hill, is 1,200 ft. above the sea. Unlike the higher grits, these sandstones rarely present escarpment faces. They are thrown into a succession of sharp folds, on the north and south axis, and the declivities are generally dip-slopes. On the west the strata arch over and end abruptly against the New Red Sandstone which underlies the Cheshire plain. Their base is not seen, so that no measurement of their total thickness can be made. The thickest bed of crowstone may be nearly 100 feet thick, and is succeeded by two or three thin beds (15 or 20 feet) with separating shales. The shales with earthy limestone and marine bands have yielded *Goniatites* and *Aviculopecten papyraceus*, fossils common to measures lying above the 1st Grit. The series of grits in the Millstone-grit (3, 4, 5) is poorly represented. The long mural escarpments with broad valleys of softer strata which characterise the formation to the north and east have here given place to complicated ground, broken by cross valleys and faults into detached hillocks, where the only conspicuous shale features are those which separate the millstones from the Kerridge sandstone above and the shale-grit below. A close examination of the ground shows that the four divisions of the millstones are still present, but the shales which separate them are mere partings. Three miles to the north-east the grits open out into a succession of escarpments and dip-slopes, but they are there nearly 400 feet thicker than at Macclesfield.

The strata with coal-seams and the Kerridge sandstone are generally grouped with the Lower Coal-measures, but the grits do not differ essentially from those of the Millstone-grits, so that here, as elsewhere in England, the division between Coal-

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measures and Millstone-grit is quite arbitrary. The seams of coal are of small commercial value, and the few mines in which they were still worked at the time of the original geological survey of the district are now closed. The overlying sandstones form a conspicuous feature at the eastern edge of the Cheshire plain. They are largely quarried on Kerridge hill and at Bollington, and occasionally yield fine specimens of plants. Three distinct beds of sandstone, separated by shale partings, can be traced. Mr. Gibson.

Further south, in the Biddulph and Congleton areas, Mr. Wedd finds a more complete series of the Lower Carboniferous rocks. The uppermost beds of the limestone which are brought up on a sharp fold in the quarries at Astbury, are associated with interbedded agglomerates and tuffs, as described by Messrs. Gibson and Hind.* They are succeeded by a series of calcareous shales and thin bands of dark impure limestone containing small goniatites, and a thin seam of impure coal lying 15 feet above the highest bed of tuff. Between these and the 3rd Grit a series of shales and grits forms the hill-slopes between the Astbury quarries and Congleton Edge. The four millstone grits of the Macclesfield area have apparently dwindled down to two, representing the first and third grits of the northern area. Along Mowcop a coal nearly four feet thick lies on the top of the third grit, and was formerly worked. A thin coal also overlies the first grit. Mr. Wedd.

On the east side of the Biddulph Valley a coal corresponding in position to the Crabtree coal of Wetley Moor and Cheadle can easily be traced from Wickenstone to within a few yards of Woodhouse farm. The shale-roof contains numerous specimens of *Goniatites* and *Aviculopecten*, of the same species as occur above this coal in the Cheadle area. On the west side of the Biddulph Valley this coal seam has not been found, but its position is probably marked by a thin band of pebbly grit 250 feet above the first grit, which is similar to the grit forming the floor of the coal on the east side.

Owing to the steep dip of the strata and the covering of superficial deposits, little is seen of the measures above the first grit. It is certain, however, that they include no massive grit comparable to the Kerridge rock. The strata in the Biddulph Valley are thrown into a synclinal fold with a north and south axis, the position of which is accurately shown by a level course in the Newpool (Cockshead) coal at the Bradley Green Colliery.

The structure of the complicated ground between Harecastle and Astbury lime-works has not yet been fully made out. It is of considerable importance with reference to the occurrence of coal beneath the Triassic deposits to the west, and has received much local attention.

Culm of Devon and Cornwall.

A few additional particulars have been gleaned by Mr. Ussher regarding the development and distribution of the Culm-

* *Quart. Journ. Geol. Soc.*, vol. lv., 1899, p. 548-559.

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Mr. Wedd. measures of Cornwall and Devon. In the region coloured Devonian on the published maps, he has found that some miles to the north of St. Germans, rocks resembling the Middle Culm appear in the form of fine, more or less, felspathic grits or sandstones, and dark shales or mudstones, with which they are occasionally interbanded. Lower Culm-measures form a small, inlying, anticline at the north end of Amy Down. They also occur on Tor Down, Herod Down, Crendle Down, and Warrenleigh Plantation, Newton Ferrers House, and Dunnerdake. They consist of hard, shaly, and dark mudstones, with cherty bands and dark banded slaty shale, in which no definite succession could be detected. In the south part of Herod Down hard shaly beds, apparently in the upper part of the series, contain *Posidonomya* and *Goniatites spiralis*. In the adjacent road soft beds of the Brimley type occur. No limestones have been met with.

The Culm-measures around Chudleigh were surveyed on the old one-inch map in 1887, when no subdivision was contemplated beyond their separation from the Devonian Series. The district, north and west of Chudleigh, has been found to present the following succession in the Lower Culm-measures below the grits and shales of the Middle division:—

5. Hard and soft shales and hard, dense mudstones, with occasional bands of pale grey siliceous limestone and of chert. *Posidonomya*.
4. Cherty rocks and dark chert-beds intercalated with hard mudstones.
3. Local evidences of contemporaneous vulcanicity.
2. Very hard, dark, bedded mudstones, with thread-like, whitish banding at intervals.
1. Dark grey shales or slates.

The Lower Culm rocks have not yet been separated in the districts between Chudleigh and Kingsteignton, nor south of Bovey Tracey; but, in the area W. of Chudleigh, from Doddiscombsleigh to Bovey Tracey, their boundary with the overlying shales and grits is a well-marked stratigraphical line.

Advantage has been taken by MR. USSHER of the construction of the Teign Valley Extension Railway to examine the cuttings laid open along the line. Among Culm shales and grits of the Exeter type he observed in Perridge Tunnel an anticline which brings up dark mudstones containing *Goniatites*. This observation taken together with another made in 1887 near Tedburn St. Mary, where the uppermost beds of the Lower Culm were found with small *Goniatites*, demonstrates the constant repetition of the Culm rocks between Chudleigh and the Crediton valley, and proves that the upper beds of the Lower Culm are of a distinctly argillaceous character, while the overlying rocks are of the Exeter type.

GRANITE OF CORNWALL.

The various bosses of granite which in the south-west of Cornwall pierce the "killas" are not improbably like those of Devonshire, younger than the Culm-measures. But reference

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may most conveniently be made to them in the present section of this *Summary*. Those which extend from the Land's End to St. Ives and from Marazion towards Helston have been mapped by MR. WILKINSON. The large mass which lies to the west of Falmouth is now under examination by MR. HILL, who supplies some preliminary notes regarding it. **Mr. Wedd.**

The mapping of the granite has so far been limited to the examination of a portion of the great Penryn mass. It is a grey acid, coarse-textured muscovite-granite consisting of orthoclase and plagioclase, abundant quartz, and both white and black mica, together with tourmaline in varying proportions. Porphyritic felspars are commonly distributed, and include individuals of idiomorphic orthoclase exhibiting twinning of the Carlsbad type. Although not so coarsely crystalline as some of the other Cornish granites, which contain porphyritic felspars of large size, like those of the Land's End type or of the mass near St. Austell, yet the Penryn rock presents a texture which, as compared with other British granites, is not only coarse as regards the matrix, but also in the size of its porphyritic felspars which are often 2 or 3 inches in length. Although both muscovite and biotite are usually present, every variation may be observed in their relative abundance. In some sections muscovite may occur almost to the exclusion of the biotite, while in others the mica may be almost entirely biotite. Tourmaline occurs both as a constituent of the ground mass in which it generally takes the form of stumpy prisms, and as a later introduction coating the faces of joint planes in needle-shaped crystals which tend to dispose themselves in bunches. These needles sometimes attain a length of 2 or 3 inches. Tourmaline seems to be a conspicuous mineral in the more acid portions of the granite which vein the normal type. In some veins of coarse, acid granite tourmaline occurs to the exclusion of biotite, and some of the individuals have been noticed under these conditions as large as half an inch. Where such coarse acid veins have been observed to contain tourmaline as well as massive schorl, contiguous veins which are finer in texture are found to be rich in biotite, while tourmaline is then entirely absent. In the coarse veins containing tourmaline the mica that occurs is muscovite. Other instances have been observed where the only mica contained in the coarse acid veins is a white mica. **Mr. Hill.**

In that part of the Penryn granite which has yet been mapped no perceptible change of texture has been noticed at its outer edges. It should be mentioned, however, that sections showing actual junctions of this rock with the slate are rare, yet if the mass is looked at as a whole, a distinct difference of texture may be detected in it between the marginal parts which, broadly speaking, are finer grained than the interior, and are found to be somewhat heavier than the coarser grained material.

The comparative uniformity in the direction of the major joints in the granite over the whole Cornish area was long ago pointed out by DE LA BECHE. In the Penryn district, one set of vertical joints, having a prevalent direction of N. 10 deg. W., is

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Mr. Hill. crossed by another vertical set at right angles. These two systems, in conjunction with a third set more or less horizontal, divide the whole rock into a set of roughly prismatic segments. The great regularity of these joint planes has been an important factor in the rapid development of the granite industry of Cornwall, as compared with other localities in Britain. The joints have received local names. Those which trend N. 10 deg. W. are known as *cleaving way*-joints, those at right angles are the *tough way*-joints, while the horizontal joints are known as floors or *quartering way*-joints. The grain of the granite has been found to correspond with the position of the joints, hence their names.

The rock cleaves most readily along planes parallel to the floors or horizontal joints. The next easiest cleaving plane is that parallel to the cleaving way-joints (N. 10 deg. W.), while the rock cleaves most irregularly parallel to the tough-way joints. This rule is understood to hold good over the whole granite area. An examination of numerous sections in which all three types of jointing are visible appears to show a distinct tendency to orientation along planes parallel to the horizontal floors and to the cleaving-way joints, though no absolute regularity in this respect has been observed. While in many instances these joints trend away from the normal direction; it is unusual to find more than one joint deflected in the same exposure. The horizontal joints, although they often undulate, are the most regular of all. The cleaving planes of the rock are not always strictly parallel to the joints, yet, on the whole, the marked parallellism between the joints and the directions along which the rock most readily cleaves is unmistakable. From the evidence of a large number of sections there is reason to conclude that not only is there a close connection between the major joints and the grain of the rock, but that this grain is dependent on the internal mineral arrangement of the rock, and that all three phenomena are closely related. The uniformity in these structural features appears to be diffused over the whole granite mass, and may perhaps be found to be common to the whole of the granites of the West of England. The internal crystalline arrangement appears to consist first in a tendency for the mica to lie with its basal planes horizontal; secondly, in a disposition of the felspars both as constituents of the matrix and as porphyritic individuals, with their flat sides in a similar position; and thirdly, in the orientation of the felspars with their long axes parallel to the cleaving-way joints. The first and second of these structures probably explain the proneness to cleave parallel to the horizontal joints, while the third seems to show why the rock tends to cleave in planes parallel to the cleaving-way joints. The rock, however, presents no structures so defined as those of foliated rocks. It does not differ to any marked degree in outward appearance from ordinary granite. Yet it has evidently undergone a rude and initial stage of foliation, whereby its component minerals have been forced to rearrange themselves in a definite direction so as to acquire a cleavage.

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The tough-way joints, or those which correspond roughly to a direction E. 10 deg. N., may sometimes be faults, instances being common where the horizontal floors have been thrown by them as much as 2 feet, or where the joints display slickensided surfaces indicative of relative displacement of the walls. Further, the finer-grained granite veins tend to take a course parallel to these same joints, while the elvan dykes undoubtedly follow the same parallellism. a Mr. Hill.

The horizontal joints or floors form one of the most characteristic features as seen in the field. De la Beche considered them as original structures and not as produced at a comparatively late period by the decomposition of the outer crust. The fact that these horizontal joints have been faulted by the joints bearing E. 10 deg. N. proves them to be at least older than these tough-way lines of division. Later joints, however, occur which cannot always be distinguished from the true "floors" into which they appear to blend. The intervals between these horizontal joints or floors increase with depth from the surface. In one of the quarries the joints are 60 feet apart, while in another they are so favourably disposed that blocks of stone can be produced 120 feet long, 28 feet wide, and 30 feet deep.

The elvans display considerable irregularity in their jointing. One of these dykes, intruded along the "tough-way" of the granite, has a common "quartering-way" joint with that mass, while one of its dominant joints corresponds with the "cleaving-way" joints of the granite.

Although the junction of the granite with the slates can be rarely seen, the contact metamorphism of the latter may be sufficiently studied. As stated in former Reports, it presents an aureole of "knotted" slate, the innermost portions of which are crowded with minute scales of muscovite and biotite, while at the actual junction andalusite is abundant. The phenomena thus differ considerably from those displayed by the Land's End granite, near to which the sedimentary rocks are indurated and change into hornfels to such an extent that it is often difficult to distinguish these rocks from the greenstones.

As the survey of Cornwall has so recently been extended to the mining districts, the examination of the lodes has only been begun. The districts of Camborne and Redruth are now the principal seats of the mining industry, which is more or less scattered over the country. Notwithstanding the length of time since the Geological Survey maps of this district were completed and published, the principal mining operations are still carried on in the old lodes which are shown on the original maps. Tin is being extracted at present from a group of mines in the Camborne district at depths varying from 200 to 450 fathoms. The tin lode known in the district as the Great Flat lode has, however, been discovered since the first survey. It is extensively mined for tin, the workings descending to a depth of 300 fathoms. Besides these more important tin-producing mines, minor operations are conducted nearer the surface on lodes down to a depth of about 20 fathoms.

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Mr. Hill. The tin-stream-washing is almost at an end in the county, but operations of this kind are still carried on at Perran Porth and at Pen Pons near Camborne, while the advanced price of tin has led to the working of the old mining burrows with profit in various portions of the county. While tin forms the principal mineral at present raised in the county, copper is also worked, together with other metals, including arsenic, wolfram, and uranium.

Triassic.

Leicestershire.

Mr. Fox-Strangways. The revision of the geological maps of Leicestershire and adjoining counties has led to a more precise delineation of the boundary-lines of the Triassic formations of that district. Thus, along the northern side of the Wreak Valley, between Melton and Loughborough, the Keuper Marl and Rhætic group have been separated by Mr Fox Strangways. The Rhætic outcrop has been traced northwards from Barrow, and the dark paper-shales are well exposed at Barrow Hill resting on the tea-green marls, with a thin bone-bed between them. Thence the outcrop may be followed through the village of Walton until it is lost under boulder-clay. Again, along the eastern side of the Soar Valley, where two well-marked outliers of Rhætic and Liassic strata rise to the south and west of Gotham, the Keuper Marls contain an important bed of gypsum, which is extensively worked near the village, and has been traced for several miles. The outcrop of the Rhætic beds is well shown along the steep sides of these outliers, but the bone-bed has not yet been detected here.

Staffordshire, Shropshire, and Cheshire.

Mr. Barrow. In the Cheadle district further progress was made last spring by Mr. Barrow, who mapped an additional tract of Bunter Sandstone and Keuper Marls. The most interesting part of his work consisted in the detection of some indications of discordance, possibly due to contemporaneous erosion in the Triassic series, and accompanied by traces of slipping along the sides of pre-Triassic valleys.

Mr. Gibson. The Bunter group has been found by Mr. Gibson to be well developed around Market Drayton, where it is exposed in many natural sections. Possibly, however, only one of the three subdivisions of the group is here represented. Bands of false-bedded, laminated, non-pebbly, mottled red sandstones, indistinguishable from those usually classed as "Lower mottled," are developed at several horizons throughout the pebbly subdivision. One of these bands, occurring high up in the middle subdivision, has been mapped as Lower Mottled Sandstone on the published one-inch map. Near Tern Mill the non-pebbly sandstone can be seen resting on the coarse conglomeratic sandstones which rise to the south of Market Drayton. Near Tyrley Lock the lower subdivision may

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be represented, but it passes upwards imperceptibly into the middle subdivision. In North Staffordshire the lower portion of the Bunter group may be said to consist of slightly pebbly sandstones, conglomerates, and shingle beds, with lenticular bands of non-pebbly sandstone, developed at the base and at higher horizons, but more frequently near the summit, when it constitutes the upper mottled subdivision. The coarseness of the sandstones and the frequency of the shingle-beds rapidly increase from west to east, till at Cocknage, on the south-eastern margin of the coalfield, the Bunter is represented by strong conglomeratic sandstones and numerous bands of coarse shingle, thus approaching to the Leicestershire type, which consists of shingle beds enclosing lenticles of sandstone. Mr. Gibson.

In the Macclesfield district, which is undergoing revision by Mr. Pocock, the New Red Sandstone is almost entirely buried under thick drift. A ridge of it runs in a south-easterly direction from Alderley Edge, and comes to the surface near Radcliffe Wood. Yellow sandstones with a few small pebbles abut against the steep slope of Yoredale sandstones. No great thickness of sandstones is seen, and they pass up conformably into red marls, which overlap the sandstones till they come into contact with the Carboniferous rocks. The Trias rocks do not show any sign of disturbance along the line of junction, their boundary-line pointing rather to their having been deposited against a steep face of Carboniferous rocks. Mr. Pocock.

In the Congleton district surveyed by Mr. Wedd the junction of the newer and older formations is undoubtedly a fault. Thus in the stream flowing west from Congleton Edge through Limekiln Wood the Trias can be seen faulted against Carboniferous strata. A faulted junction is also visible half-a-mile west of Mowcop close to Grotto Wood. In the Lawton Pit, west of Harecastle, the red rock is proved in a stone drift, and the junction is described as a fault. The workings of the Bunkers Hill Colliery also prove the junction between the Trias and Coal Measures to be a fault of unknown amount with a downthrow to the west. The western margin of the Pottery Coalfield along its entire length from Madeley to Talke is bounded by a large fault which can be proved to affect both the Trias and Coal Measures at Bar Hill, Mucklestone, and Madeley Manor. Mr. Wedd.

In the small strip of Trias, on the western flanks of Mowcop and Congleton Edge, the Bunter division is seen at intervals. East of Mowcop station the Keuper division is faulted against Bunter, and soon passes under red marls which gradually overlap the Bunter formation.

Isle of Arran.

The important discovery of Rhaetic fossils in Arran, announced in the *Summary of Progress* for 1899, was followed up last year by a further search, which was rewarded by the discovery of a large assemblage of fossils of Rhaetic, Liassic, and Cretaceous ages. The strata containing these fossils are not in place, but occur as large masses within an old volcanic vent, into which

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Mr. Wedd

they must have fallen from above. The circumstances of their occurrence will therefore be more appropriately described in the pages of the present volume, which treat of the Tertiary volcanic rocks of Scotland. It may suffice to state here that the discovery of masses of abundantly fossiliferous Rhætic shale in Arran affords the strongest proof that the newer red sandstones of the southern half of the island are really Triassic. The age of these strata has long been in dispute. They have been regarded as Old Red Sandstone, Carboniferous, and New Red Sandstone. It is interesting to note that the final determination established by the fossils confirms the original conclusion of SEDGWICK and MURCHISON that the rocks belong to the "New Red Sandstone."

The discovery of Rhætic fossils in Arran has led to the re-examination of some specimens collected by MR. H. B. WOODWARD in 1892 in the passage-beds between Trias and Lias at Eyre Burn, on the south of Raasay. The fossils recognised by MR. E. T. NEWTON are *Modiola*, *Pecten*, and *Pleuromya*, cf. *crowcombeia*, not sufficiently definite in themselves to prove their Rhætic age, but interesting to record, as similar and better-preserved examples have since been found in Skye in the passage-beds between Trias and Lias.

Jurassic.

CAMBRIDGESHIRE AND HUNTINGDONSHIRE.

During the past year it was found desirable to trace some new lines over a considerable area of the eastern half of Sheet 187 (new series) in the counties of Cambridge and Huntingdon. MR. WEDD, who was detailed for this duty, separated the Ampthill Clay, with the Elsworth and St. Ives Rock at its base, from the Kimeridge Clay above and the Oxford Clay below. He has traced the outcrop of the Elsworth and St. Ives band more or less continuously for some twelve or fifteen miles from the neighbourhood of Croxton in the south, through Yelling, Papworth Everard, Elsworth, Hilton and Fen Drayton to the Ouse Valley in the north; and again on the north side of the Ouse Valley, from Houghton Hall in the west, through St. Ives, Needingworth, and Holywell. It appears that all the ground to the east of this outcrop for some distance is Ampthill Clay, while that lying to the west is Oxford Clay. A layer of phosphatic nodules has, where seen, been taken as the upper limit of the Ampthill Clay, as suggested by the late T. ROBERTS.

ISLE OF ARRAN

In the same Tertiary volcanic vent to which reference has been made in the Triassic section of this *Summary* large blocks of dark shale are likewise included, from which a number of characteristic Lower Lias fossils have been obtained. An account of these fossils will be given in the Palæontological sub-division. Their discovery is of the highest interest, as they clearly prove that the Lower Lias extended from the north of Ireland at least as far as the present basin of the Clyde.

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Isle of Skye.

Mr. Wedd. As it was necessary to complete the mapping of the Jurassic formations of Skye with a view to the publication of one of the Sheets of the map, and as Mr. Woodward's administrative duties prevented him from continuing his former survey there, Mr. Wedd took up the work where Mr. Woodward had left it. Stationing himself on the west side of the Jurassic district, he found immediately below the Tertiary basalts on the west side of Loch Slapin a series of dark, sandy, micaceous shales and shaly sandstones, with many hollow casts of Belemnites, and Ammonites, and *Pecten fibrosus*. The presence of Ammonites, which appear to be *A. cordatus*, shows these beds probably to belong to a horizon not lower than Upper Oxfordian. They are underlain by a well-marked horizon of blue sandy limestones and calcareous grits, with thin shales and a bed of small oysters (*Ostrea hebridica ?*), apparently of estuarine origin, and belonging to the Great Oolite or Loch Staffin series. These pass down into shales full of crushed lamellibranchs (*Cyrena ?*), overlying a white saccharoid sandstone, 30—40 feet thick, apparently of freshwater or estuarine origin (Inferior Oolite ?). This passes down into marine shales with indeterminable ammonites, and below these shales comes a thick series of white sandstones and grey calcareous grits, with marine fossils (*Terebratula* sp., *Rhynchonella tetrahedra ?*), forming the cliffs on the west side of Loch Slapin.

When traced northwards to the head of Loch Slapin, the upper part of the Jurassic formations is seen to be much metamorphosed in the neighbourhood of the Tertiary granite of the Red Hills. The oyster-bed can be recognised as a grey mottled marble, and the black shales are seen for some distance to be baked into a substance resembling white porcelain. On the east side of Loch Slapin, at its head, hardened sandy shales are faulted in against the Durness limestone. These have all the appearance of Pabba shales, but no determinable fossils have yet been found in them. On the east side of Loch Slapin, further south, the *Bucklandi*-zone of the Lower Lias is seen to overlap the Durness limestone. In Strath the subdivisions of the Lower Lias, suggested by Mr. Woodward for the Broadford district, hold good for some distance westward. The base of the Lias is here marked by a series of whitish pebbly grits; a few feet should apparently be assigned to the Rhætic group, but there is no definite plane of demarcation from the Trias. Lower, pebbly Triassic sandstones, with a bed of red and green marls near the top, lie unconformably on Torridon Sandstone or on Durness Limestone; but the Trias and the lowest strata of the Lias disappear in turn westwards owing to the overlap of higher stages of Lias.

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Cretaceous.

Wiltshire and Dorset.

Mr. Clement Reid. The detailed mapping of the Vale of Wardour by Mr. Clement Reid has clearly proved the conformity of the Wealden to the Purbeck strata. It has also shown that a nearly steady eastward dip affects these rocks, and that they were denuded and truncated before the so-called Lower Greensand was deposited on their upturned edges. The only representative of the Lower Greensand that can be found here seems to be some 20 or 30 feet of coarse glauconitic sands, more or less loamy, and containing nodules of cherty sandstone. These sands appear to lie perfectly conformably to the Gault above, though separated from it by a bed of pebbles. At their base, there is usually a similar bed of pebbles, which rests unconformably on various strata of older date. No clear evidence for any other Lower Greensand has yet been found in the Vale, and as corresponding strata a few miles to the south-west have been shown by Mr. R. B. Newton to yield the fauna of the zone of *Ammonites mammillatus*, it seems probable that the deposits in the Vale of Wardour also represent this highest division alone of the Lower Greensand. Sections of these strata are here rare, and the only fossils that could be found were sponge-spicules and moulds of *Pecten orbicularis* and *P. 5-costatus*, all contained in loose blocks of cherty sandstone, which are so like certain parts of the Upper Greensand that one cannot be perfectly sure that surface specimens are of older date.

Dr. A. W. Rowe's work on the variation of the Micrasters has proved useful in this district, which yields sub-zonal forms like those obtained on the coast. By means of these fossils it is now possible accurately to trace the lower boundary of the Upper Chalk in regions where the Chalk Rock cannot be found, or in which there occur two or three beds of Chalk Rock.

In view of the growing urgency of the question of water-supply throughout the South of England, it is most important to ascertain accurately the limits and thicknesses of the different divisions of the Chalk, which is one of our principal water-bearing formations. Slight undulations, such as were overlooked in this homogeneous rock before the divisions were mapped, are now known to form underground water-partings, by raising the hidden impervious beds below; these shed the water in opposite directions, and isolate catchment areas formerly thought to be continuous. A thorough knowledge of the limits of these catchment areas is a necessary preliminary to the allotment of the different basins to different towns or districts. It should be borne in mind that where the surface rocks are porous the numbers and limits of these basins do not correspond at all closely with the supposed "catchment areas" or river basins mapped out in the ordinary way by surface contours.

Mr. Dixon. In the Upper Cretaceous area around Maiden Newton (Sheet 327), Mr. Dixon notes the sharp lithological and palæontological

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division between the Lower Chalk and the Upper Greensand the lowest part of the Chalk being glauconitic, sandy marl, usually crowded with phosphatic fossils, especially Cephalopoda of Lower Chalk age; whereas the uppermost part of the Greensand is a hard, coarse, calcareous and glauconitic grit, containing *Pecten asper* and other Upper Greensand fossils. Mr. Dixon.

Sussex.

The area surveyed in this county last year by Mr. Lamplugh, measuring 41½ square miles, completes the survey of Sheet 317 of the New Series One-inch Map, and as the results obtained will be published shortly in the Memoir on that Sheet, only a brief outline of them need be given here. The ground lies mainly to the east of the Arun River, and consists, in its southern portion, of the Upper Greensand, Gault, and the various subdivisions of the Lower Greensand described in the *Summary of Progress* for 1899, and in its northern portion, of the Weald Clay. It includes the western part of the "Greenhurst anticline," where a narrow tongue of Weald Clay is brought up by a sharp fold in the Lower Greensand. Mr. Lamplugh.

The Lower Greensand and overlying divisions showed little alteration from the characters already described, and will not be further discussed.

The Weald Clay was examined over a triangular tract with a base four miles in length at the eastern edge of the ground, and its apex in the west, near Petworth. Where broadest, probably about half the total thickness of the Weald Clay was represented in this tract. It included a considerable portion of the area mapped and described with remarkable accuracy by Mr. P. I. Martin so long ago as 1828. The bands of sand and of Sussex Marble by which this observer divided the Weald Clay into belts were traced out wherever possible, and although found not to be quite so regular and continuous as he supposed, their general succession was in full agreement with his descriptions. The details of these bands and their local distribution will be given in the forthcoming Memoir. The occurrence of the sandy horizons has much economic consequence, as they are the main source of water supply in the Weald Clay tract; and moreover by their admixture with the clay where near the surface, they change the character of the soil from an untractable clayland, which under present conditions will not pay for cultivation, to a more readily arable loam. Beds of this character underlie the major portion of the arable land in this part of the Weald, while the unmodified clay-belts lie for the most part under grass or woodland. The beds of sand, though thus materially affecting the land, are usually too thin or too much interstratified with clay to make a really "light" soil, especially as the clays tend everywhere to "creep" and become mixed with the sands along the outcrop.

The water-supply from wells in the sands is often tainted with mineral matter in solution, and is usually only sufficient in

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Mr. Lamplugh.

quantity for household supply, but is important in a district where no other safe source is available.

The sands and limestone bands generally form gentle features along their outcrop, but owing to their slight thickness and the above-mentioned "creep" of the clays on the slopes, it is rare that the beds are visible in these features, the exposures being usually found in gutters and ponds, on the lower part of the long gentle dip-slope under a thickness of 2 or 3 feet or more of clay.

There is every gradation between sand and clay, the silty intermediate beds being often finely laminated. From the spoil-heap of a new well, sunk to a depth of 40 feet in beds of this description at a cottage opposite to Marringdean Farm, south of Billinghurst Station, a few well-preserved plant-remains were obtained. These were submitted to MR. A. C. SEWARD, F.R.S., who kindly undertook their determination and recognised the following species:—

Weichselia Mantelli, Brongn.
Onychiopsis Mantelli, Brongn.
Brachyphyllum sp.

The flora of the Weald Clay, as distinguished from that of the Hastings Beds, is imperfectly known, so that the occurrence of these plants is of some interest, though they belong to widely distributed Wealden forms. The horizon at which they occur is about midway in the Weald Clay of this part of Sussex.

Atherfield Clay.—Comment was made in last *Summary of Progress* on the difficulty in obtaining definite evidence respecting the Atherfield Clay in Sussex. During the present year, however, indications of the presence of this clay were found at several points, the clearest being in a road-cutting near Warminghurst, at the eastern margin of the ground surveyed, where the sandy Hythe Beds are seen to pass down into greyish brown and chocolate-brown clay, with small phosphatic concretions containing casts of marine shells. This clay, which was apparently not more and might be less than 20 feet thick, rested directly and sharply upon dark blue shaly clay, evidently the topmost bed of the Weald Clay. This confirmation of the correctness of the old map in regard to the presence of the Atherfield Clay in Sussex is the more satisfactory since the new railway-cutting at Redhill, on the opposite side of the Weald, showed the unexpected absence of the division.

SURREY.

In regard to the Redhill section, just referred to, it may be stated that during last summer the railway-cutting between Redhill and Earlswood, on the London, Brighton, and South Coast Railway, was widened, and that as this cutting exposes the junction of the Lower Greensand with the Weald Clay, which is so rarely visible, the opportunity was taken for studying the section during the progress of the work. The results are of considerable interest, especially in showing the unexpected

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absence of the Atherfield Clay, this deposit having hitherto been supposed to be continuous all around the Weald, as indicated on the published geological map. The section exposed on the eastern side of the cutting, and now again concealed, was as follows:— Mr. Lamplugh.

Hythe Beds:—	ft.	in.
Ashy grey and yellow loamy sand with large ferruginous concretions towards base; containing many casts of shells in the lower part and in the concretions, including *Exogyra*, *Terebratula*, *Lucina*, *Pholodomya*, *Pecten*, and *Pinna*, seen about	12	0
resting sharply on—		
Weald Clay:—		
Dark shaly blue clay much broken up, and partly mixed with loam which has apparently filled borings in the clay	0	4
Dark blue clay more or less interlaminated and interbedded with greenish-grey and whitish silt, much crumpled and broken in places in the upper part	4	9
Brown indurated clay with laminæ of pale silt; containing many Cyprids, and fragments of fishes	0	3
Laminated blue and black clay and pale silt; the thicker silty beds much broken	2	0
Brown indurated clay, with shells at base, including *Cyrena*, *Vicarya*, and *Ostrea*	0	2
Laminated blue clay and pale silt, with a band of small pyritous nodules	2	7
Dark clay streaked with white silt, with a 2 in. brown band crowded with cyprids and fish-remains	4	6
Clay-ironstone band, with cyprids, fish-scales, etc. (much broken towards outcrop)	0	3
Dark shaly clay with greenish-grey silt in laminæ and in thin beds	9	6
Clay-ironstone band full of *Cyrena*, cyprids, and fish-remains, also containing *Vicarya*, *Cardita*?	0	3
Dark shaly blue clay containing shells as above, also a small oyster	1	0
Blue clay streaked and interbedded with pale silt	7	9
Dark clay streaked with silt, containing shells (*Unio*?) at base	2	8
Clay ironstone band with cyprids, fish-remains, and shells—*Cyrena* and *Paludina*	0	2
Dark blue clay streaked with pale silt, lower beds not seen	2	6
Thickness of Weald Clay examined	38	8

There was no sign of weathering, erosion, or unconformability at the top of the Weald Clay in this section, except that it appeared to have been penetrated for a few inches by the burrows of marine organisms. The superficial crumpling and breaking up of the bedding which prevailed for some feet below the junction was probably due to slight differential creep or drag between the clay and the overlying mass of sands during consolidation; it is a feature commonly to be observed under like circumstances in the softer Secondary formations. The Weald Clay of this section bore a remarkably close resemblance lithologically to the Wealden shales occupying a similar position at the top of the Wealden series in the Isle of Wight, and the presence of brackish water

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Mr. Lamplugh.

forms among the fossils in both places establishes the correlation. As similar forms have been recorded from the top of the clay at two other localities in the Weald,* one lying far to the eastward, and the other to the westward of Redhill, it is probable that the incoming of marine conditions is foreshadowed throughout the whole area by fossiliferous bands of this character, although the junction with the base of the overlying marine series appears to be everywhere sharply drawn.

The marine fossils mentioned in the Weald Memoir (p. 113) as having been obtained from the Atherfield Clay in a railway-cutting near Redhill, about one-third of a mile to the eastward of that above-described, appear, on reference to the original account given by FITTON, to have been collected from concretions at the base of the Hythe Beds similar to those found in the recent section, and cannot therefore be taken as proof of the presence of the Atherfield Clay at that point.

ISLE OF WIGHT.

The Lower Cretaceous coast-sections in the Isle of Wight were examined by MR. LAMPLUGH during a short visit at the end of September for the purpose of comparing them with the rocks of the same age recently surveyed in Sussex, and of obtaining information for the General Memoir on the Lower Cretaceous formations of England. The material collected during this visit has not yet been through the hands of the palæontologists, so that the wider results of the investigation cannot at present be given, but opportunity is taken to place on record a few facts which add to our knowledge of the subject.

1. Fossils were found in the Carstone, in the form of casts in small phosphatised concretions, wherever this division was accessible, viz., at Redcliff, near Sandown; at Bonchurch Cliff; on the slopes south-east of Blackgang (the best collecting ground); and at Compton Bay. The majority of these fossils are probably species already included in the scanty published list from this division, but some are new to it. They include some imperfect *Ammonites*, perhaps not determinable but certainly not *Ammonites mammillatus*.

2. The Sand-rock series in the slopes south-east of Blackgang yielded casts of marine bivalves and plant-remains in a band of ferruginous concretions 10 feet below the base of the Carstone. Shells do not appear to have been previously recorded from this division.

3. In the Ferruginous Sands of Little Stairs Point, south of Sandown, there occurred a transported slab of Kimeridge shale, measuring 8 in. × 6 in. × ½ in., much bored by pholades, which is of interest in showing that erosion of the Upper Jurassic rocks was in progress at no great distance during the deposition of these sands. The slab was also interesting in that it contained, along with other fossils, numerous specimens of a

* See Survey Memoir, "Geology of the Weald," pp. 98-99.

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small delicately-sculptured organism at present undetermined, but possibly a crustacean, which was only previously known to us from a low horizon in the Kimeridge clay in one of the recent deep borings in Kent. Mr. Lamplugh.

4. On the beach and at the foot of the cliff a little to the southward of Shanklin Chine, an irregular pebble-bed, containing pebbles up to 4 inches or more in diameter, was exposed in the Ferruginous Sands, which does not appear to have been previously observed. The larger pebbles, mostly subangular or partly rounded, were composed of a pale green-stained sandy rock, partly made up of fragments of shells, which may represent a decomposed sandy limestone or chert, possibly derived from the Purbecks; other pebbles were of brown sandstone, and many of the smaller ones, well-rounded, up to an inch and a-half in diameter, were of white vein-quartz. The pebbly band was associated with fine clay and silt containing large pieces of fossil wood. This is the coarsest pebble-bed known in the series in the Island, and as it occurs in the middle of a subdivision, with no sign of erosion or unconformity in the underlying bed, it shows how little confidence can be placed in the mere presence of such a bed, as evidence for a break in the sequence.

5. As regards the general correlation of the Lower Greensand of the Wealden district with that of the Isle of Wight, it is clear that the divisions adopted in the respective areas, on lithological consideration, have not their boundaries in common, and, therefore, cannot be directly compared. Neither are the fossils sufficiently numerous or distinctive to give much hope for palæontological classification, since the bivalves which constitute the principal element in the fauna are mostly of wide range in time, though apparently rather narrowly localised in their mode of occurrence, or, at any rate, in their preservation. The Trigonias seem to offer the most likely prospect of service in this direction, and might be worth further study.

The following seems on the whole to be the most probable relationship of the Lower Greensand divisions of the two districts:—

Isle of Wight.	*West Sussex.*
Gault.	Gault.
Carstone.	Folkestone Beds.
Sand-rock Series.	
Ferruginous Sands.	Sandgate Beds.
	Hythe Beds.
Atherfield Clay.	Atherfield Clay.
Wealden Shales.	Upper part of Weald Clay.

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Oxfordshire.

Mr. J. H. Blake.

The Lower Greensand has been resurveyed by Mr. J. H. Blake at Nuneham Park and around Marsh Baldon. To the east of the latter place he found in more or less cherty sandstone beds some marine fossils, of which the following have been identified by Mr. E. T. Newton:—

Ammonites sp. Three fragments, one of which may be *A. nutfieldensis*, but is too imperfect for identification.

Pecten orbicularis, Sow. Two specimens.

Cardium, near to *peregrinorsum*, d'Orb.

Astarte? Small inflated shell with few concentric ribs.

Ostrea sp. Five specimens, may be several species.

"Although the specimens can scarcely be taken to prove the strata to be of Lower Greensand age, yet their general facies points to that conclusion."—E. T. N.

The only fossils previously recorded from the sands, presumably Lower Greensand, in this district were *Ammonites Deshayesi* and *Terebratula sella*, which were found in the road-cutting at Toot Baldon by Prof. (Sir A.) Ramsay, Mr. Etheridge and Mr. Hull, during a tour of inspection about the year 1860 or 1861. The sands in many parts of Nuneham Park are of a coarse quartzose character. A recent excavation west of the Lodge in the south-eastern corner of the Park, showed 4 feet of chocolate-coloured coarse quartzose loose sand overlying 4 feet of ferruginous and indurated coarse sand, thinly bedded, locally known as "roach," and used for metalling paths.

Modifications have been made in the boundaries of the Gault in the neighbourhood of Stadhampton, Chislehampton, and Drayton. The hill to the north-west of Chislehampton has been proved by a boring 60 feet in depth, made this year near the top of the sloping ground opposite Church Farm, to consist of bluish-grey clay, blackish in places. It is apparently Gault overlying Kimeridge Clay; whereas, it is shown as Lower Greensand on the Geological Survey Map, Sheet 13 (Old Series).

At Clare Brick-works, two miles N.E. of Chalgrove, a new section 3 feet in depth showed light blue-grey clay, containing a little "race," a few ferruginous concretions, and some small phosphatic nodules. Mr. Blake obtained a portion of *Ammonites (Schlœnbachia) rostratus*, Sow., identified by Mr. E. T. Newton.

Isle of Arran.

Mr. Peach and Mr. Gunn

The same great volcanic vent, which has been already referred to as proving the former extension of Rhætic and Liassic strata into the basin of the Firth of Clyde, has likewise yielded large included masses of white limestone and chert, from which numerous unmistakeable Chalk fossils have been obtained. These are further referred to at pp. 111 and 112. They are alluded to here for their importance as proofs that the Upper

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Cretaceous rocks, which now end off on the north coast of Antrim, once stretched eastwards at least as far as Arran. Indeed there seems no reason why these later Mesozoic formations should not have spread far over the south of Scotland. The denudation of that region since Tertiary time, as proved by the numerous wide and deep valleys cut across the younger dykes, has been so enormous as to have removed hundreds of feet of material from the surface of the country. Mr. Peach and Mr. Gunn.

Tertiary.

Hampshire Basin.

The past season having seen the completion of the re-mapping of the Hampshire Basin, this may be a convenient point at which to summarise the leading results obtained by the new Survey of the Tertiary deposits of this region. Without going into minor details, we may state that the main points brought out are: The striking tendency of the successive divisions to become gravelly and to overlap lower ones towards the west and south-west, as though high land lay in that direction. This is well illustrated by Mr. Reid's observations of coarse gravel with much Palæozoic material at the base of the Reading Beds towards their south-west limit, where also they have cut deeply into the Chalk. In the Bagshot Sands also there is a general increased coarseness of the material towards the west; and ultimately where the Sands overlap the Lower Eocene and rest on the Chalk they change into coarse gravels, like those of the Reading Beds, but containing also fragments of Jurassic rocks, and of greywether sandstone. A slighter overlap seems to occur at the base of the Bracklesham Beds. Finally, during the past season, Mr. Dixon has shown that the pebbly base of the London Clay also cuts through the Reading Beds, and rests upon Chalk. Mr. Clement Reid.

The Oligocene strata are preserved over so limited an area that no overlap of them has been proved. There occurs however, a striking change towards the south-west, in which direction tufaceous limestones—entirely absent on the mainland, and rare and thin to the north and north-east, become conspicuous at several stages in the Headon Series of the Isle of Wight, while land-shells and angular stones are more abundant than elsewhere. It looks as if these strata within two or three miles might have been found to abut against older deposits, were it not that all direct evidence has been destroyed by denudation. Another point brought out by the 6-inch mapping is the greater sharpness and depth of the east and west folds. For instance, an increased thickness and a large additional area of Hamstead Beds has been proved in the Isle of Wight syncline, the Portsdown anticline has been shown to extend much further west than was thought, and the Chichester syncline has been traced eastward till it loses itself beneath the sea.

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Mr. Clement Reid. Though the mapping of the Hampshire Basin has now been completed, it is probable that a chain of outliers of the Bagshot river-gravels will connect the Eocene of Dorset with that of Bovey Tracey in Devon—indeed, several outliers of this gravel have already been mapped. The amount of Eocene material in the Clay-with-Flints is so great as to point also to a much wider extension of the Eocene strata in every direction in past times.

Mr. Dixon. In the Cranborne district (Sheet 314) Mr. Dixon finds that the marine bed at the base of the Reading Series, mentioned in the last *Summary*,* is persistent throughout the area examined. New fossiliferous localities have been found in the London Clay, the fossils, however, being chiefly in the form of casts. The detailed mapping of the London Clay has brought out the fact that in places where the basement-bed contains much shingle it passes across the basset edges of the Reading Beds on to the Chalk.

In the Maiden Newton district (Sheet 327) Mr. Dixon has mapped another Eocene outlier, probably of Bagshot age. It contains flints of every degree of angularity, as well as much Palæozoic material, and subangular fragments of silicified *Cyrena*-limestone, probably derived from Purbeck strata. As the horizon of the Chalk on which this deposit rests is only about 280 feet above the Chalk Rock, it is evident that the overlap of the Bagshot Beds, mentioned in previous *Summaries*, becomes more pronounced as the mapping is extended westward.

Oxfordshire and Buckinghamshire.

Mr. Blake. The outliers of Reading Beds at Russellswater Common, Turville Heath, Summer Heath, and Southend Common, Ibstone and Lake End, all north of Henley-on-Thames, have been re-mapped by Mr. Blake. The first three outliers, which in many places are covered by a thin deposit of loam and flint-pebbles, apparently derived from the local Tertiary Beds, consist entirely of Reading Beds, of little thickness, whereas the Lane End outlier (including Moorend Common) includes five outliers of London Clay above the Reading Beds. Moorend Common is apparently enclosed by four faults as shown on the original Geological Survey Map (Sheet 13). At the brickyard S.-E. of Muzwell Farm, a clean-cut section showed the stratified white and buff sands of the Reading Beds dipping in a south-westerly direction towards the fault on the eastern side of the Common; while on the roadsides south-west of the Common, the Reading Beds dip in a north-easterly direction towards the fault on the western side of the Common. Consequently, it would appear that there must be a considerable fold in the Chalk, which may have contributed to the faulting of this area.

There are faults also at Cadmore-End Common, which have not been previously noticed. One in the northern part runs in

* *Summary of Progress* for 1899, p. 139.

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an easterly direction, having a downthrow of the Reading Beds to the north, with the Chalk at the surface to the south; another trends in a south-westerly direction, with a downthrow of the Reading Beds to the west. Mr. Blake.

At Bolter-End, north-westward of the four crossways and south of Cadmore-End Common, an oval-shaped hill, which measures 12 chains in length by 7 chains in width, is entirely composed of flint-pebbles. In a gravel-pit on the eastern part of this hill a vertical section, from 9 to 12 feet thick, has been laid open, without exposing the bottom of the deposit. It presents a mass of closely compacted pebbles, which MR. BLAKE believes to be a pebble-bed of Tertiary age *in situ*, an opinion shared by MR. H. B. WOODWARD when he inspected the section. On the sloping ground around, sand and sandy loam, several feet in thickness, belonging to the Reading Beds and containing much iron sandstone, was seen to intervene between the pebble-bed and the Chalk.

At the brickyard at Kiln Wood, on the west side of Cadmore-End Common, sections of Reading Beds have been exposed, showing mottled clays overlying from 16 to 18 feet of white sand, in which latter impersistent bands of bluish-black sand occurred, varying from about 2 to 4 inches in thickness. A sample of this dark material, taken by MR. H. B. WOODWARD, was examined chemically by DR. W. POLLARD, who reports as follows:—

"The specimen treated with strong hydrochloric acid leaves an insoluble residue of quartz and a little clayey matter. The solution contains alumina, iron, manganese (as peroxide), cobalt, and nickel. Small quantities of lime and magnesia are also present."

The occurrence of cobalt and nickel in the Reading Beds has not hitherto been recorded.

VOLCANIC SERIES OF THE ISLE OF ARRAN.

During the past year the important discovery by MESSRS. PEACH, GUNN, and MACCONOCHIE of Mesozoic fossils among the blocks of strata entombed within a large volcanic vent in the Isle of Arran has not only thrown new light upon the former extension of Rhætic, Liassic, and Upper Cretaceous formations over the south of Scotland, but has in the most extraordinary manner furnished evidence as to the geological age of the great series of younger igneous rocks for which this island has been so long famous. MACULLOCH long ago showed that the granite of Arran was probably later than the surrounding red sandstone, for no fragments of it were to be found in these strata. The petrographical resemblance of the assemblage of Arran rocks to those of Antrim and the Inner Hebrides subsequently led to the inference that they not improbably belonged to the same great Tertiary volcanic period.* By the discovery of masses of Messrs. Peach and Gunn.

* *Trans. Geol. Soc. Edin.*, Vol. II., Part iii. (1873).

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Messrs. Peach and Gunn.

hardened Upper Chalk in the great volcanic vent of this island, this inference has now been confirmed in the most singular and unexpected way. This vent broke through a covering of Mesozoic strata, which included a sheet of hard chalk like that of Antrim. The explosion was thus certainly later than the Upper Cretaceous period, and may consequently be unhesitatingly referred to older Tertiary time. The fixing of the age of this vent carries with it the determination of the age of all the associated eruptive rocks. There can now be no room to doubt that the granites, quartz-porphyries, felspars, pitchstones, diorites, diabases, and basalts are all a connected series of eruptive masses, coeval with the similar assemblages in Antrim, the Inner Hebrides, and St. Kilda.

In previous *Summaries of Progress* reference has more than once been made to the existence of a geological complex, which has been mapped by Mr. Gunn. Lying south of the road leading from Brodick to Shiskine, it is of an oval form, about 3½ miles in length by 3 in breadth. A portion of it is probably the most intricate piece of ground in the whole island. It is bounded on the north by the Machrie Water and on the south by the Clachan Glen. On the east side it extends to the head of Glencloy, and it includes all the highest ground in the island south of the high granite hills, there being three summits (A'Cruach, Beinn Bhreac, and Ard Bheinn), between 1,600 and 1,700 feet above the sea, arranged in a semicircle round the head of Glen Craigag, which glen nearly divides the complex into two equal parts.

This area is made up of fragmental material interpenetrated in all directions, and much altered, by intrusive igneous rocks of various kinds. Much of the fragmental material is in character very like that composing different members of the Old Red Sandstone, and as it occurs in the centre of an area occupied by that formation, it was natural to suppose that these altered rocks were of the age of the Old Red Sandstone. It must be confessed that this view was not free from difficulties, for in many places it was observed that most of the included fragments in the rock were of igneous origin—*e.g.*, quartz-felsites and granites—which do not occur in the Old Red Sandstone of other parts of the island. Some of the rock was also seen to resemble volcanic agglomerate. Patches of marmorised limestone had also been noted in the area, as well as some masses of shale, and of white or light-coloured sandstone, unlike anything observed in the Old Red Sandstone of other parts of the island. In the early part of the year fossils of Rhætic age were obtained by Mr. Macconochie from one of the shale patches, but the relation of this shale to the adjacent fragmental rocks was not easy to explain till Mr. Peach, on a visit of inspection to the ground, came to the conclusion that the main rock of the complex was an agglomerate of igneous origin filling a great neck or volcanic vent.

The fragmentary material can be traced over an area 2½ miles in length, by 2¼ in breadth, and it may have once extended

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much farther, for it is now surrounded by an almost continuous ring of intrusive igneous rocks chiefly of an acid character. Messrs. Peach and Gunn.

The general character of the fragmental rock differs much in various places. The matrix often has a great resemblance to that of an ordinary sandstone, and in it are embedded pebbles and blocks of a great variety of igneous rocks—those of an acid character generally predominating. Sometimes, as in Creag Shocach, east of Glenloig House, the rock is a red sandstone which might easily pass for a member of the Old Red series. In several places it is a coarse conglomerate like the characteristic quartzite conglomerate of the Lower Old Red Sandstone. But, on the whole, the included fragments are more or less angular, so that the rock is rather a breccia than a conglomerate, though in only a few places does it assume the character of an agglomerate, entirely made up of igneous material. Fragments of basic lavas are not at all common in it.

Several large patches or fragments of different formations have been enclosed in the vent, some of which, as above stated, have been identified by their fossil contents as being of Rhætic, Lias, and Cretaceous ages. The largest of these, which is of an irregular shape and several acres in extent, contains not only beds of Rhætic age, but grey and red marls of the age of the Lias. This occurs in Allt-an-Dris near Derenenach, and was described with its fossil contents in last year's *Summary of Progress*.

Rather more than a mile to the south-east of this locality another shale patch occurs near the head of Ballymichael Glen, and about half a mile due south to the top of Ard Bheinn. The exposure in a dry gully on the north-west side of the stream is not large, but the rock may extend for a length of 100 yards, Mr. Peach was the first to obtain organic remains from this shale, and from their general character he pronounced the rock to be Lias. The fossils first obtained were not well preserved, but Mr. Macconochie has since collected a numerous suite of undoubted Liassic specimens in better preservation, which Mr. Newton has identified. Another patch of shale intensely altered and now of a blue colour, is found about three quarters of a mile south of Glenloig House, but no fossils could be obtained from it.

About 200 yards south of the Lias shale in Ballymichael Glen, and close to the stream, blocks of a cherty or siliceous white limestone occur in the conglomerate, and some may be observed lying in the bed of the stream. These blocks have yielded foraminifera of Upper Cretaceous age. A similar limestone is found in a cave rather more than half a mile to the north-east of Derenenach, some of it much altered by contact with igneous rock, being now a white marble. It contains irregular siliceous lumps (chert or flint) like those which occur in the blocks at Ballymichael Glen. Another place in which white limestone occurs is situated about 550 yards south of Glenloig, and here the limestone was formerly worked, though little is

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Messrs. Peach and Gunn.

now to be seen. The rock is free from siliceous material, but it is much altered, and it has furnished no organic remains. In the neighbourhood of the Derenenach cave several small swallow holes prove the existence of other patches of limestone which cannot be seen at the surface.

In addition to these patches of limestone and shale some large and small pieces of a light-coloured sandstone have been noticed, perhaps of Jurassic age, but none of them have yielded any fossils. The largest of these masses occurs about 650 yards north-west of Beinn Bhreac, and is 300 yards in length. Some smaller patches are found 100 yards south-west of the Derenenach cave, and 200 yards south of the same cave lies a large mass of a similar sandstone, the boundary of which is not well defined, but it is probably 50 or 60 yards in diameter. Another occurs to the south of the Rhætic Beds. These fragments of Secondary formations (which once covered at least the southern part of the island of Arran) have fallen from above into the vent of a large volcano, which was active at some time later than that of the Upper Chalk.

The Newer Red rocks, which cover so large a portion of the island, are now shown to immediately underlie the Rhætic Beds, and must, therefore, belong to the Trias. In the southern part of the island (the geology of which has been published as Sheet 13), they were classed provisionally as Permian because the lowest member—a false-bedded red sandstone—is similar in character to the Ballochmyle red sandstone near Mauchline, in Ayrshire, which had been considered as of Permian age.

Volcanic Series of the Isle of Skye.

Mr. Harker.

Information gathered by Mr. Harker during the survey of the western part of the Cuillin Hills, as regards the highly complex relations of the Tertiary igneous rocks of Skye, has necessitated some revision of certain parts of the area mapped by him in former years. This has been carried out, with the result that 78¾ miles of new boundary-lines have been added to the map. The chief alterations called for were the separation of the intrusive sills from the basaltic lavas on the Strathaird plateau, and the delineation of the boundary between the gabbro on the northern fringe of the Cuillins and the highly metamorphosed and entangled basalts.

The remaining portions of the Cuillin range itself and the neighbouring basaltic tract to the west have been completed. In the former, the chief interest relates to the rocks of the peridotite group enveloped in the gabbro of the south-western Cuillins. These rocks have been mentioned incidentally in a former Report. They have now been examined in detail and found to have considerable importance and interest. The principal mass is a very irregular laccolite which forms the western peak of the Sgùrr Dubh ridge, and extends eastward down An Garbh-choire and northward into the lower part of Coireachan Ruadha. It is not only enveloped in the gabbro, but traversed by countless dykes

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and veins of that rock. Indeed, the north-eastern border of the mass, about Allt a' Chaoich, is of a character which defies mapping, showing a gradual transition from peridotite traversed by a network of gabbro veins to gabbro enclosing detached blocks of peridotite. The latter are found in gradually diminishing numbers as far as the shores of Loch Coruisk and Loch Scavaig. Mr Harker.

The rocks themselves, which we group as peridotites, are in large part picrites, but there are also abundant types richer in olivine, including pure dunite. Norite occurs locally, and a troctolite, rich in olivine, is often associated with the typical ultra-basic rocks. Two striking features, both indicative of heterogeneity, characterise the rocks as seen in the field. One is the extraordinary prevalence of *débris* of one type of rock enclosed in a matrix of another type; the other is the banded structure which affects in greater or less degree almost the whole of the group, alternating bands differing considerably in petrographical type. One phase of this is the occurrence in the dunite of thin seams composed wholly of picotite.

These plutonic peridotites clearly belong to the oldest intrusions of the Cuillins. There are other ultra-basic rocks, in the form of dykes, which belong to the youngest, since they are found to cut every other rock which they encounter.

Another place where Tertiary igneous rocks have been mapped during the past season is the Isle of Scalpay. The volcanic group is represented here by a small area of basaltic lavas in the southern part of the island. These rocks, resting on Lias to the west, and cut off by a fault to the east, have a thickness of not less than 1,600 feet. In the south-western part of the island an extension of the granite of Skye invades the Torridonian strata, branching out in one place into a succession of sheets. Of the minor intrusions of Scalpay, the most interesting is a group of dykes which belong to the general model of the triple composite dykes of Skye, consisting of granophyre, flanked on each side by basalt. In this outlying area, however, the dykes show great irregularity, in the deficiency of one or other of the component rocks, a sinuous line of outcrop and frequent interruptions of continuity. These imperfections throw considerable light on the nature and origin of the more typical examples in Skye.

Tertiary Igneous Rocks in West Argyllshire. — In the Eas Ruadh glen, six miles south of Oban, numerous dykes, chiefly of basalt, present chilled edges in contact with the andesites. They are split up by newer acid dykes, which are so much weathered that the normal aspect of the rock can only be inferred from the undecomposed rhyolite bombs found in the volcanic rock south of Glen Feochan, in which beautiful flow structure is well shown. As these acid dykes have been injected into the basalt-dykes they may be inferred to be of Tertiary age.

'The Craignish promontory, eight miles south of Kilmelfort, displays two compound basalt dykes, of which one runs from Barbreckmore in a N.W. and S.E. direction, and the other a mile

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Mr. Harker. to the south-west extends in a parallel direction from the Free Church to Daill, and forms the sole of the road between the two places. In the northern portion of the island of Luing a compound basalt dyke runs in a N.E. and S.W. direction north of Ballahuan. It is found also in the tideway between Luing and Torsay islands.

Pleistocene, including Glacial.

In the course of the field-work last year considerable tracts of Glacial Drift were mapped, and various details were collected which help to increase our knowledge of the history of the Ice Age in Britain. A brief summary of the observations is all that can be given here. In the following narrative a geographical order will be adopted. The English Southern Counties and Midlands will first be taken, then the region of South Wales, and, lastly, the various areas of survey in Scotland from south to north.

Sussex.

Mr. Lamplugh. The high-level flinty rubble, described in last *Summary of Progress* as having been traced by Mr. Lamplugh in this county, has been again found by him under the same conditions, though in less quantity, on the higher ground occupied by the Folkestone Beds to the east of the Arun, at Rackham, Parham Park, Kithurst, Sullington Warren, and Longbury Hill, forming little plateaux at varying elevations, apparently the remnants of an old surface which sloped westward towards the Arun Valley and also northward from the Downs. The remarkable persistence of this drift on the Folkestone Beds, while it is scarce or absent on the neighbouring formations, seems to be due to the greater height of the outcrop of that group, which, perhaps, thus alone preserves portions of the ancient surface on which the rubble was deposited.

There is the same difficulty on the eastern as on the western side of the Arun Valley in distinguishing between the lower patches of this high-level drift and the higher of the true river gravels, though frequently the presence of fragments of chert, sandstone, &c., in the latter is sufficient to identify them.

Where the escarpment of the Hythe Beds is high, as between Petworth and the Arun, patches of angular cherty rubble, derived from that source, occur as a thin capping on hills of Weald Clay below the escarpment and sometimes half a mile or more distant from it. These usually lie opposite coomb-like indentations in the escarpment, and are probably equivalent to the flinty rubble which occupies a similar though more distant position in regard to the South Downs. Both would require peculiar physical conditions for their production, and are probably the relics of some stage of the Glacial Period.

Gravelly deposits, undoubtedly connected with the erosion of the present valleys, were found under the same conditions as described in last *Summary of Progress*, chiefly in the form of

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deltas around the junction of tributary streams with the main valleys, their materials being mainly derived from the high-level drifts. These gravels, in the absence of sections, are sometimes difficult to detect, owing to the deep covering of stoneless sandy wash in the Lower Greensand tract, and of clayey wash in the Wealden area, which form soils indistinguishable from those of the "solid" formations. Mr. Lamplugh.

In the vicinity of the Arun, gravels of this class occur at varying elevations, even capping high ground adjacent to the river, as at Lee Farm in the Weald, and at Greatham on the Lower Greensand. They are then, as above stated, scarcely separable from the high-level drift. It is indeed evident that the subaerial erosion of the land has gone on without interruption since the period of the high-level drift; there is no trace here of the marine stage recognised at corresponding elevations on the southern side of the South Downs, which therefore probably preceded the earliest drift now existing in the interior.

On the ridges of Weald clay immediately north and south of Gunter's Bridge, one mile north of Petworth, a considerable development of stratified gravel of Wealden material deserves mention, as there seems to be no drainage at present in this locality which will account for it. The gravel occurs, however, at the extreme northern margin of the area surveyed, and may receive explanation from the examination of the tract farther north.

Flints were observed in considerable numbers in the soil of the cultivated lands on the Weald clay, especially in the vicinity of the Arun, but they become scarcer towards the north. A few smooth pebbles of quartzite and two well-rounded and pitted flints, evidently from Tertiary pebbles, were also found under similar conditions. Whether these have been introduced in the process of cultivation or whether they have formed part of the gravels could not be ascertained, but their presence deserves further investigation; if in place, they may indicate a temporary northward inflow through the Arun gorge at some period in the past.

Oxfordshire and Buckinghamshire.

The mapping of the Loam and Clay-with-Flints on the Chiltern Hills has been continued by Mr. Blake northwards from Russellswater Common (south-east of Watlington), and from the north of Medmenham to Chinnor Hill. In many places patches of mottled clays and loams are to be seen, which are evidently re-deposited Reading Beds. They are more sandy, not plastic, and much less brilliant in colour than Reading Beds *in situ*, and often contain little fragments of flints. Mr. Blake.

Several patches of Pebble Gravel were mapped and the boundaries of others were revised around the Lane End outlier of Reading Beds. The largest, extending from Dell's Farm to Chequers Farm, N.W. of Lane End, overlies the Chalk, and consists of large and small flint-pebbles, intermixed with

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Mr. Blake.

angular and sub-angular flints, in a matrix of yellow, orange, and buff-coloured loam, sand, and clay. The highest part of this gravelly patch is about 622 feet above sea level. Several patches of somewhat similar gravel occur at Cadmore End; while at Kiln Wood, west of Cadmore End Common, pockets of pebbly and sub-angular flint-gravel, ten feet in depth, occur in the white sand of the Reading Beds, which latter present a somewhat wavy and disturbed appearance near the surface, that may possibly be due to glacial action.

Further south from Kensham Farm to the Stockenchurch-road a considerable mass of gravel may be seen. A large pit-section of this deposit shows from 18 to 20 feet of pebbly and subangular flint gravel, intermixed with and overlying re-deposited mottled, crimson, and grey clay, loam, and sand, of the Reading Beds. In the upper part of the section these strata are shown to be distinctly stratified, with gravel above and below them. The Pebble Gravel capping the two outliers of London Clay on the Lane End outlier of Reading Beds consists mostly of small flint-pebbles; but some have been noticed from three to six inches long, intermixed with a few of quartz and lydite, in a matrix of brown sand. In patches of shingly Pebble Gravel near Parmoor the flint pebbles vary from one to three inches in length, and are intermixed with a few of quartz, Lydian stone, and subangular flints, in a matrix of loam and clay.

A large spread of Plateau-gravel extends from Marsh Baldon to Draycot and Burcot. This deposit consists mostly of small flints, rounded and subangular, enclosed in a sandy matrix, with numerous rounded pebbles of quartzite, pink and white quartz, lydite, cherty sandstone, and occasional shell-fragments —much water-worn pieces of *Ostrea* being common. Further west, and also in Nuneham Park, several large areas of loam and clay, full of rounded pebbles of quartzite, quartz, Lydian stone, etc., occur at various levels on the Lower Greensand and on outliers of Gault.

LEICESTERSHIRE.

Mr. Fox Strangways.

In the east of this county, where MR. FOX STRANGWAYS has been engaged, he has found the Drift to consist chiefly of chalk-bearing Boulder-clay. This deposit caps the higher ground at Knossington, Cold Overton, and Pickwell, but descends into the valley at Owston towards the west and Whissendine towards the north. A broad stretch of country, about a mile or more in width, extending from Burrow, Somerby, and Pickwell eastwards to Ranksborough Hill and beyond, stands up free of Drift. All the valleys cut through the Drift and expose the solid strata, showing that the superficial deposit cannot be of any great thickness. Patches of gravel occur at Cold Overton, Knossington, and Owston, capping the higher ground, but there does not appear to be much sand or gravel at other horizons. The relation of these accumulations to the Boulder Clay is obscure, but they appear to be more or less contemporaneous with it.

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According to PROFESSOR JUDD,* these gravels are much contorted and disturbed, but since the introduction of roadstone from the older rocks, the fine sections formerly exposed have been entirely obliterated. In the *Summary of Progress* for 1899 the erroneous mapping of the Drift in this district, as shown on Sheet 64, was pointed out. The revision last year has shown further errors, more particularly to the north of Cold Overton, where a palpable Upper Lias country with fine sections in the Rock Bed of the Middle Lias is shown as Drift. Mr. Fox Strangways.

In the district traversed by the Wreak Valley the Drift is of considerable diversity, and somewhat unique. There are certainly two if not three Boulder Clays of different ages, and also beds of gravel of two or three periods, but it may be doubted whether there is sufficient evidence for the very numerous subdivisions introduced by MR. DEELEY.† He may possibly have given different names to the same deposit in different localities. MR. FOX STRANGWAYS, however, reserves his opinion on the true succession of these deposits until further work has been done by him in the Trent basin. The present Wreak Valley appears to traverse an old glacial basin which was more or less filled up with brickearth and sand before the deposition of the Chalky Boulder-Clay. It is in the N.E. corner of this district that the large boulder or drifted mass of oolitic limestone occurs, 300 yards long by 100 yards broad, which was mentioned in the *Annual Report of the Geological Survey* for 1892.

In the northern part of the district mapped by MR. FOX STRANGWAYS there is not much Drift, though a little is found capping the hills around West Leake. It descends to lower levels towards the Soar Valley, where it becomes mingled with post-glacial deposits, and is then difficult to distinguish from them. The latter become extensive along the lower part of the river as it approaches its junction with the Trent. The fault bounding the Lias on the south side at Normanton Hills, which is shown in the old map 71 S.E., is well seen in the cutting of the new line of the Great Central Railway.

SHROPSHIRE.

The town of Market Drayton stands on bare Bunter Sandstone, but MR. GIBSON has observed that immediately to the west the Drift appears and increases in thickness so rapidly as to suggest that the ground on which the town is built is a pre-glacial bluff of Triassic sandstone, against the western scarp of which the glacial sands and gravels have been banked up so as to bring it on a level with the Cheshire plain. To the south of Market Drayton, round Hinstock, the Drift is thick and consists largely of loamy sand. To the east and south-east it occurs in small irregular patches of no great thickness. Near the head of Coal Brook, however, between Fairoak and Chipnall Mr. Gibson

* *Geology of Rutland*, in *Mem. Geol. Survey*, fig. 19.

† *Quart. Journ. Geol. Soc.*, vol. xlii., p. 437.

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Mr. Gibson. Mill, a considerable thickness of gravel and sand encloses swamps and extensive peat-bogs. The gravel consists largely of small pebbles of Scotch granites, mixed with a few quartzites derived from the Bunter conglomerate. Among the large erratics, which are strewn over the surface of the ground, granites from Southern Scotland are far in excess of those from Cumberland. It would appear that a tongue of ice from the great sheet covering the Cheshire plain carried to this place boulders chiefly derived from the South of Scotland.

The coarse beds of the glacial sands near Market Drayton yield numerous fragments of marine shells, those of *Turritella* being the commonest. They are frequently nearly perfect, but are very fragile.

CHESHIRE.

Mr. Pocock. From the observations of the glacial phenomena in the Macclesfield district, continued by MR. POCOCK last year, he has found it possible to trace out the limits of glacial action in this part of England. No striated surfaces have been detected, the only evidence as to the direction of ice-flow being furnished by the distribution of erratic blocks. Boulders of Millstone-grit, most probably derived from the high ground east of Macclesfield, are scattered over the Lower Carboniferous sandstones of Croker Hill. As the gathering ground does not extend west of a line drawn north and south through Croker Hill, it would seem that the ice followed a more southerly direction than is usual in the north-west of England. This trend is quite in accordance with the disposition of the great physical features which must have controlled the movement of the ice-sheet in this part of the country.

All the hill-tops up to 1,300 feet show, by perched blocks of igneous rocks from Cumberland and Southern Scotland, that they have been overridden by the ice. The first check to the southward progress of the ice seems to have been given by the high ground of Macclesfield Forest, where a dome-shaped hill, a square mile in extent, rises to a height of 1,570 feet. Boulders of Cumbrian and Scottish rocks are found all round the slopes up to a height of 1,330 feet, but no higher. Most likely the summit stood up as a "nunatak," even at the time of greatest glaciation. Two miles further south the ice encountered a more formidable barrier. The conical peak of Shutlingslow stands on an elevated plateau about 1,300 feet above the sea, separated by a deep ravine from the main ridge of the Pennines, the peak itself being 1,658 feet in height. This ravine, known by the name of Wild Boar Clough, contains northern erratics deposited on the flank of the main ridge to a height of 1,100 feet, which shows that the ice must have flowed completely round Shutlingslow. This plateau is, for the most part, free from drift and boulders, but the ice penetrated a shallow depression on the west side of the peak, where the ground sinks to 1,200 feet or less, and left a train of gravel mounds along a line two miles in length. The peak itself,

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together with all parts of the plateau which rise above 1,300 feet, are destitute of drift and boulders. Nor is it likely that they ever existed here, since the country is uncultivated moorland, where there would be no occasion to remove boulders, as has been done in the low-lying agricultural districts. Mr. Pocock.

We have now the materials for forming an estimate of the thickness of the ice sheet on the west side of the Pennine Chain. The level of the Trias Sandstone under Macclesfield at its lowest point is 317 feet above the sea; the highest boulder in the same latitude is 1,330 feet. If 100 feet more be allowed for the surface of the ice, the thickness would be 1,113 feet. Probably it was rather less in the southern part of the area, as the limit of boulders around Shutlingslow seems to be some 50 feet lower than it is further north. An estimate of 1,000 to 1,100 feet for the thickness of the ice-sheet in this district will not be far from the truth.

Search was made for any indications of local glaciation, but none were found. Boulders from the main ridge of the Pennines do not seem to have been carried to the westward. Indeed, the northern ice approached so close to the foot of the ridge that it is not likely to have encountered any resistance, as it would have done if an ice-cap had covered the ridge itself.

The Drift in the country round Macclesfield is of two kinds, which may be called respectively Boulder-clay and Fluvio-glacial deposits, the former term being restricted to those deposits which are the direct product of land-ice, and the latter being used for those in which the materials are ice-borne, but the depositing agent was water. It is sometimes difficult to separate the latter from the more modern river-gravels. The Boulder-clay comes to the surface over a small part of the area only, all of which is above the 500-feet contour line. So far as Mr. Pocock has yet observed, all the clays at a lower level belong to the fluvio-glacial series. A thickness of 20 feet or more of Boulder-clay extends up the valley from Sutton to Cleulow Cross, where, at a height of 1,000 feet, the ice passed over the watershed into the basin of the Dane. A section about a mile above the village shows a tough amorphous clay with striated and rounded boulders, many of which are derived from the Lake District Volcanic Series. This appears to be a true till formed under the ice, which came up the valley from the north-west.

Similar deposits cover a considerable area in the valley at Langley, and rise gradually as they are traced up-stream, till at the 1,000-feet level they die out. There are, besides, numerous sheltered spots in the hills where little patches have been lodged in positions which have protected them from subsequent denudation.

The fluvio-glacial deposits cover most of the lower ground, and are found up to a height of over 1,250 feet above the sea. They vary in character from a tough brown, finely-laminated clay, entirely free from boulders, to coarse gravels and boulder-beds, but one and all of them bear marks of deposition by water. Interesting sections of these deposits are given by

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Mr. Pocock. borings in different parts of the country, which illustrate the changeable character of the beds and the small part played by true Boulder clay in the glacial deposits of this region.* At the Macclesfield Asylum 220 feet of Drifts were bored through, with a layer of Boulder clay 44 feet thick in the middle. At the North Cheshire Brewery, a mile distant, two layers of Boulder clay, 12 and 13 feet thick respectively, were encountered in 150 feet of Drift, while at Bollington more than 200 feet of fluvio-glacial deposits were passed through without a single seam of Boulder clay. The peculiar character of these deposits seems to be due to the fact that two rivers, the Bollin and Dean, draining a considerable area of the upland country, emerge on to the lowlands at Macclesfield and Bollington. No merely local melting of the ice-sheet, caused by sub-glacial streams, is sufficient to account for the wide distribution of this kind of drift. The melting must have been general over a wide area, and was probably aided by the two rivers flowing against the ice-foot and liberating large floods of water. Parts of the ice-sheet may still have lingered in the upland valleys, and caused the rivers to flow with greater volume, but the main mass had retreated from the hills, and only occupied the Cheshire plain. The belts of Boulder-clay included in the fluvio-glacial series may indicate oscillations of the ice-front of more or less magnitude, but whether these constitute distinct periods of glaciation comparable to those which obtained in the Alpine region is not clear. The upper parts of these drifts yield evidence of the formation of a lake of considerable extent. Thick beds of finely-laminated brown clay, with occasional banks of sand, can be seen at intervals all along the foot of the hills east of Macclesfield at a level of about 500 feet. They are sometimes covered by a bed of coarse gravel, made up of waterworn stones, local and erratic, which mark the shore line of the lake against the hill slope. The lake seems to have terminated about three miles south of Macclesfield, where a ridge of Trias abuts against the Carboniferous hills above the 500-feet level. Part of the site of the lake is now occupied by a peat-bog called Dane's Moss, not far from the town. On the west side this site is bounded by ridges and mounds of gravel and sand, but on the north there is open ground as far as the Mersey 12 miles distant. Unless the lake was held in by ice on this side, it probably covered the whole of that tract. At present the lacustrine deposit has been traced as far as Bollington, three miles north of Macclesfield. A considerable delta was formed by the river Bollin, where it flowed into the ancient lake. A deposit of gravel 12 feet thick may be seen at Sutton overlying a silty clay above the present stream-level. The gravel consists of well waterworn Cumbrian erratics, mixed with more angular local blocks 6 or 8 inches long, and is no doubt derived from a boulder-clay which has been re-assorted by the stream. The delta is about half a mile wide at this point and 520 feet above the sea. Its

* See Sainter's "Rambles Round Macclesfield."

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surface rises gradually as it is traced up stream, and the deposit dies out in the village of Langley a mile higher up. The lacustrine clays show no sign of disturbance by floating ice, so that it is probable that the ice-sheet had retreated from this part of the country at the time of their formation. Mr. Pocock.

The Drifts of the upland country belong to an earlier period than those which have been just described, though they may have been formed during the dissolution of the same ice-sheet. They occur in two groups, one of which (that near Walker Barn) was referred to in the last *Summary of Progress*. The other lies on the plateau at the west side of Shutlingslow peak, and can be best examined in some gravel-pits a short distance north-east of Cleulow Cross. The top consists of coarse water-worn gravel made up of northern erratics and local rocks, underneath which are beds of sand showing beautiful diagonal bedding.

Both groups run across the cols which separate one drainage area from the other. They could not, therefore, have been formed while the present drainage system was in operation; but they are found in precisely those places where the streams would be compelled to flow if the adjacent valleys were filled by ice up to a level of 1,100 or 1,200 feet. Probably the *mer de glace* had sunk down somewhat from its highest limit, and the waters liberated by the melting ice combined with those that flowed off the higher hills to form a tumultuous stream by which the glacial *débris* was heaped up in mounds and ridges in the lowest ground then open. Other mounds of sand and gravel can be seen in the valleys resting on Boulder clay at about the 700-feet level. These have the characters of true kames, and were formed after the present system of streams had become established, but at the same time under glacial conditions. The well-known glacial shell-beds in Macclesfield Cemetery, which were many years ago described by Dr. Sainter and Mr. Darbishire, are now closed. The level of these deposits is about 450 feet above the sea. The shell-beds that lie at higher levels (1,250 feet) are also covered, but Mr. Pocock had the opportunity of examining some of the specimens which were collected at Cleulow Cross. These were chiefly rolled fragments, and included none which could positively be affirmed to have been *in situ*. The list of species is given by Dr. Sainter in his book on "Rambles Round Macclesfield."

Some instances of buried river-channels have been observed in the course of the survey. The best instance is one recorded by Dr. Sainter, which has been proved by borings in different parts of Macclesfield. The river Bollin at present flows on the east side of the town, at a level of 440 feet above the sea, the Trias sandstone being about 45 feet below the river-bed. Borings in the western part of the town have proved the existence of a trough in the Trias at about 60 feet lower. In pre-glacial times the Bollin must have flowed in a bed 100 feet lower than at present. The other examples may be seen close to the uppermost of the Langley reservoirs near the source of the Bollin. An old channel, filled up with gravelly drift, extending in a

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Mr. Pocock. south-westerly direction from the north side of Trentham Bank Wood to Ridgegate Farm, where it joins the present bed of the Bollin. The brook, which is one of the tributaries of the Bollin, has turned aside and cut a new channel through the solid rock at Trentham Bank Wood, joining the main stream a quarter of a mile higher up than at present. A similar instance may be seen at the lower end of the reservoir. Here the Bollin, leaving its old course blocked with Drift, has cut a ravine 100 feet deep in the Millstone-grit nearly 300 yards further to the south.

Mr. Wedd. In the Congleton district the superficial deposits have recently been mapped by Mr. Wedd. He finds that the Drift, entering the Biddulph Valley by the gap in the grit ridge at Mossley Village, continues for some distance to be fairly thick and to be steeply banked against the higher Carboniferous ground. But it often thins out unexpectedly, and little or none of it is to be found on much of the low ground in the southern part of the valley where it might be expected to occur. The material consists of sand and clay, clay usually overlying sand, the latter containing shell fragments near Gillow Heath Station. In this district the Drift in places is not more than 20 feet thick, the underlying Keuper Marls being seen in several places, but it becomes thicker to the west of the town of Congleton. Here also clay usually overlies sand, the latter containing shell fragments. Large erratics are far less numerous than in the district to the south.

South Wales.

Messrs. Strahan, Tiddeman, and Cantrill. The mapping of the superficial deposits in the western part of the South Wales Coal-field and the adjoining districts has been continued by Messrs. Strahan, Tiddeman, and Cantrill. The following summary of the recent results obtained with regard to the glacial geology has been drawn up by Mr. Strahan, under whose supervision the survey of the district is placed.

In the area surveyed by Mr. Cantrill he has observed proof of a northerly movement of the ice down the valleys on the northern slopes of the Black Mountains. In Cwm Sawddefechan there is much till which contains boulders of white grit, though chiefly composed of Old Red Sandstone *débris*; the drift of the Clydach Valley also encloses pieces of limestone, black chert, and white grit. In both cases these boulders must have been carried from south to north. The movement of the main mass of the ice, however, seems to have been along the foot of the slopes in a westward direction, for boulders of the red grits and conglomerates occur some miles east of the point at which these rocks disappear, as previously described (p. 64).

Further evidence of the westerly trend of the ice-flow is furnished by the striæ. On Cefn y Truman and again half-a-mile S.S.E. of Pont-Clydach they point N.W., the ice presumably having moved down from the higher ground lying to the S.E. At Carn Cennen they point W. 35° S., and still further west, at the source of the Gwythwel Brook, about S.W. That the upper ridges, if not the actual summits, of the Black Mountains were

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enveloped, is shown by the occurrence of Old Red Sandstone Drift within a few feet of the top of Careg yr Ogof (1,924 feet). Striæ and bevelled crags occur up to a height of 1,940 feet on Gareg Lâs, and the top of Cefn y Truman (over 1,750 feet) is striated. On Tair Carn there are boulders of Old Red Sandstone at 1,540 feet, while high up in the steep face of the escarpment at Forch Cenlan some till with striated boulders occurs at a height of more than 1,500 feet above the sea, and 600 feet above the foot of the escarpment. It is clear, therefore, that not only did the ice move westwards along the escarpment, and not directly away from it northwards, but that it covered the scarp-face to a high level. These facts can be explained on the supposition that a great body of ice was generated in central Wales, in a region of which the glacial phenomena are not yet known. Messrs. Strahan, Tiddeman, and Cantrill.

The crest of the Pennant range, which includes Mynydd Gwrhyd, Mynydd-achaf, Carn Llecharth, Mynydd y Gwair, Pen-twyn-mawr, and Craig-fawr constitutes a subsidiary water-parting. In its highest parts it reaches an elevation of more than 1,200 feet, but it is traversed by cols, the lowest of which does not exceed 850 feet. Not only the cols, but much of the range was crossed by the ice of northern derivation, for drift containing Millstone-grit and Old Red Sandstone boulders passed over into the Egel and Lower Clydach valleys, while boulders of these rocks occur within a few feet of the summit of Mynydd Gwrhyd and and Brynmawr. Again, the col between Pen-twyn-mawr and Graig-fawr is occupied by a gravelly Drift loaded with boulders of the same description, and the southern end of Graig-fawr is strewn with scattered blocks. All the valleys, moreover, which lead southwards from this mountain-tract contain an abundance of Boulder-clay in which boulders of a far northern source are common, though the bulk of the material consists of the local Coal-Measures. Here, therefore, we find another example of what has been frequently seen in South Wales, namely, the overflowing of a subsidiary escarpment by the Carmarthen or Brecknock ice-sheet and the augmentation of that flow by the generation of local ice.

Allusion has been made in previous Reports to the fact that the Drift is of a Boulder-clay type near its source, but of a sand-and-gravel type at a distance. This change is well illustrated in the great mass of Glacial material which extends from the Pennant escarpment referred to above to the neighbourhood of Swansea. Not only does it tend to pass in patches into a roughly stratified gravel forming characteristic mounds, but the whole mass assumes a gravelly aspect, while the boulders become more and more rounded as we work southwards until nearly all occur as true pebbles. The change is so gradual that it is impossible to draw a hard-and-fast line between the two types of Drift.

The tendency of the Glacial Deposits to assume the form of ridges and mounds of gravel along the valleys is well exemplified in the Tawe and Loughor valleys. Parts of Swansea are built on typical gravel-mounds, one of them rising to a height of

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Messrs. Strahan, Tiddeman, and Cantrill.

more than 200 feet above the river, while another forms the bold eminence occupied by Bryn Melin Park, near Cwm Bwrla, and a third underlies Bryn-hyfryd. Pentre School stands on moundy gravel at a height of 130 feet, and workings in the Hughes' Vein encountered the gravel at a depth of 150 feet below the sea, showing that the deposit is at least 280 feet thick. It is evident, therefore, that Swansea Vale, in the absence of Glacial gravel, would form an inlet of the sea of the same character as the Devon and Cornwall estuaries.

In the Loughor Valley there is a specially fine example of a compound gravel-ridge sweeping round from near Llandilo Tal-y-bont Church by Waun-gron, and thence again northwards, so as to present a convexity to the south, while it encloses an alluvial flat in a concavity towards the north.

Striæ on rock in place are seldom to be found in the Coal-Measures of this neighbourhood, the strata not being of a character to retain them, but some may be seen in one of the Cwm Bwrla quarries, 100 yards south-west of the reservoir. They run slightly south of west, parallel to the Pennant ridge, and indicate an overflow of ice from Swansea Valley along the route now followed by the Great Western Railway. In the Dulais Valley, on the 500-feet contour south-east of Cwm-dulais, there are striæ pointing rather north of west, and nearly parallel to the Dulais Valley, though they are on a plateau. These examples serve to confirm the inference drawn from other evidence, that the Drift had a strong westerly rather than a southerly trend.

Mr. Tiddeman reports that he has found a solitary boulder of Lias limestone in the Glacial Drift on the south-east point of Caswell Bay, and a pebble of the same rock in the raised beach about 150 yards west of Bacon Hole. As they can hardly have been derived from any known outlier of Liassic rock, he believes that they may point to the late survival of some outlier in the neighbourhood.

Dumbartonshire.

Mr. Cunningham Craig.

While completing the map of the Loch Lomond district, Mr. Cunningham Craig has made a more detailed examination of the deposits containing marine shells, for which this lake has so long been noted, and some further information has thus been obtained.

At the northern extremity of Inch Lonaig, in a small cliff, the following section is exposed:—

1.	Soil	8 inches.
2.	Rusty sand (with a few boulders)	4 feet.
3.	Boulder clay	7 „
4.	Fine clays and silts	13 „

The upper surface of the Boulder-clay (3) is irregular, as if denuded during the deposition of the overlying sands (2). The upper layers of the fine clays and silts (4), are contorted. It is in

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these fine clays and silts that the marine mollusca are found, several horizons having yielded fossils, a fine purplish clay near the bottom of the section being the most fossiliferous band. Mr. Cunningham Craig.

The lower part of the section is much obscured by talus and boulders washed out of the Boulder-clay above. Thus the alternating series of fine yellow and purple and grey clays and silts is usually partly masked. The Boulder-clay is only seen in section for a distance of 50 yards, as the cliff has been denuded to a lower level; another section, however, about 300 yards to the south-west, shows a small pipe or wedge of boulder clay among the marine deposits.

The upper limit of these deposits has been traced at distances varying from 50 to 200 yards inland, and is found to coincide with the 100-feet contour-line. Several openings were made between this level and the cliff section, and in all of these a yellow unstratified sand was disclosed. Half a mile north of Luss, a section on the roadside about 10 feet above lake-level shows similar alternations of stratified clay and silt, but beyond this to the northward no signs of these marine deposits have been detected. This additional evidence tends to confirm the suggestion put forward in the *Summary of Progress* for 1899, p. 166, that these marine deposits represent the 100-feet beach.

It is evident that a recrudescence of the glaciation has taken place while these stratified sands and clays were being deposited at some little distance from the shore. The ice, advancing from the northward, pushed a tongue of boulder clay over the marine deposits, the deposition of this boulder clay causing the contortion of the upper layers of the stratified deposits. The extreme fineness of the material of which these silts and clays are formed, recalls the "rock-flour" derived from the lixiviation of glacial detritus at the foot of a glacier. Subsequently, when the ice retreated, the upper sandy deposits were formed upon the denuded surface of the boulder clay. It appears probable that at the time these marine deposits were being formed the narrower part of Loch Lomond was occupied by ice as far south as Ross point. If this were the case, a comparatively small advance of the ice-front would bring the glacier as far south as Inch Lonaig.

Argyllshire.

In the Blackmount region smoothed, ice-worn surfaces and perched blocks have been traced by Mr. Kynaston up to a height of about 2,500 feet. Striated surfaces, however, are not seen, owing to the subsequent weathering of the rock. The later glaciers of the north-eastern part of the Blackmount, especially those descending from Coire Bà and the eastern side of the Clach Leathad range, spread out over Rannoch Moor in a general easterly direction, and among the erratics on the Moor we may now recognise characteristic types of the volcanic rocks of Meall-a-Bhuridh, Sron Creise, &c. The morainic material occurs for the most part as scattered mounds and ridges, divided by more Mr. Kynaston.

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Mr. Kynaston.

or less level tracts of peat-moss and alluvium; but wherever the ground rises, as, for instance, where the granitic mound of Beinn Chaorach, west of Loch Bà, surmounts the general surface of the moor, or on the slopes north of Lochan Mathair Etive, these mounds become thick and numerous, and contiguous with one another. Many of the granite blocks scattered over the moor are doubtless erratics, but a large proportion more probably represent granite that has weathered into huge angular blocks in place. The moraine mounds of the lateral rising portions of the moor resemble those referable to the valley-glaciers, so well seen in many of the glens. Occasionally a more high-level type of morainic material makes its appearance, consisting as a rule of finer material, and forming relatively lower mounds, which somewhat resemble in shape inverted saucers. These occupy elevated tracts and gentle slopes, and are well seen between the ridge of Craig Dubh, two miles S.S.E. of Kingshouse, and the lower crags of Meall-a-Bhuridh, where they cover a tract between 2,000 and 2,400 feet above sea-level. In the burn sections the loose material is sometimes excavated to a depth of at least 20 feet. Similar glacial material has also been observed, at a less elevation, on some of the hills on the west side of Glen Orchy.

The portion of the Moor of Rannoch, lying west of the head of Loch Laidon, is divided roughly into northerly and southerly portions by the broad ridge of Beinn Chaorach. The flatter tracts on either side are occupied by numerous lochs and lochans, and these, judging from the distribution of the alluvial material have evidently undergone, and are still undergoing, extensive silting up, and many were evidently formerly connected to form larger sheets of water. To the north of Beinn Chaorach the moor rises slightly and almost imperceptibly between Lochan Mathair Etive (Loch Mother of Etive) and the Sandy Loch (or Lochan Gaineamhach), the waters on the one side flowing to the west coast down Glen Etive, those on the other side to Loch Laidon, Loch Rannoch, and finally to the east coast.

Occasionally the morainic mounds on the moor assume the form of a low ridge which may be traced in an almost direct line for some distance. One such ridge may be followed for about 2 miles from the west side of the Dubh Lochan in a direction slightly west of north to the river Etive. Possibly this may mark a terminal moraine of the Blackmount glacier.

Around the shores of Loch Creran, and in the lower part of Glen Creran, morainic material in any quantity is entirely absent. The bare rock is almost everywhere at, or close to, the surface, and is polished and striated, the striæ being directed, in every case observed, down the glen. In the lower part of the glen, and on the hill-slopes of the north-west side of the loch, erratics of kentallenite and a coarse augite-diorite are exceedingly common, and often of large size; but neither of these rocks has as yet been found in place in Glen Creran area.

Mr. Symes.

In the district to the south of Oban MR. SYMES has found boulders of granite from the Ben Cruachan mass scattered on

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all the islands, but none like the granite of Kilmelfort. Around Scamadale Loch, seven miles south of Oban, the striæ on the north side of the glen run in a N.W. and S.E. and also in an E. and W. direction, which is wholly exceptional in this district, where the general glacial movement over a very considerable area was steadily fromN. 20 E. to S. 20 W. The anomaly is probably to be accounted for by the different flow of the later glaciation, when the great arms of the glacier followed the lines of valley. At the head of the valley S. of Glen Feochan, four miles from Oban, the striæ coincide with the direction of the glen, which trends N. 27 W. They were presumably produced by a branch from the main ice-sheet. Mr. Symes.

The older raised beaches of the West of Scotland, which form part of the records of the Ice Age, are well developed in the Oban district. The terrace of the 50-feet beach was traced by MR. SYMES last year round the islands of Luing and Torsay, and on Eilean Gamhna at the mouth of Loch Melfort.

The glaciation of the north end of the Island of Jura was studied last year by MR. PEACH. He found that the striæ on the highest cols and crests overlooking the west coast point to the movement of ice across this part of the island from E.S.E. to W.N.W. They are specially conspicuous on the ridge between Grianan Mòr and Ben Garrisdale at heights up to over 800 feet. They probably belong to the period of maximum glaciation. Nests of Boulder-clay are found in the hollows between the hills, usually beneath a coating of peat. There is abundant evidence that, after the maximum glaciation, even the small glens in this part of the island nursed glaciers, seeing that almost every glen has its group of moraines. Some of the moraines reached the sea-level during the period before the elevation of the 100-feet beach, for near the foot of Allt na Conaire moraines merge into the material of that beach. Mr. Peach.

A well-defined terrace of the 100-feet beach may be seen near the foot of Glen Garrisdale. Along the part of the shore mapped by MR. PEACH the raised beaches are chiefly represented by rock-notches (or *Seter* of the Scandinavian geologists), which correspond to the 100-feet, 50-feet, and 25-feet beaches respectively. The platform of the 50-feet beach is perhaps the most conspicuous, being generally bounded by fine precipices pierced by caves, many of which show signs of having been inhabited at various periods down to the present time, when they are taken advantage of chiefly by lobster-fishers. The rock-notches are generally bare, but sometimes they show a coating of the old shingle.

INVERNESS-SHIRE.

Over the low-lying tract that stretches from Loch Duntelchaig by Tordarroch and Wester Lairgs to Beinn a' Bheurlaich, south of Daviot, evidence has been obtained by MR. HORNE which points to the north-easterly movement of the ice sheet as it streamed outwards from the Great Glen—a conclusion already established by the observations of MR. FRASER and MR. WALLACE Mr. Horne.

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Mr. Horne. of Inverness. Striæ are rarely found on the weathered surfaces of the muscovite-biotite-gneiss, though the trend of the *roches moutonnées* indicates with sufficient clearness the direction of the ice-flow. But on the finely-polished veins of quartz or pegmatite, ice-markings are frequently preserved. West of Tordarroch, the striæ point N. 4° E.; on Meall More east of Farr school-house, E. 20°–33° N. and N. 20° E.; and on Creagan Bad Each, one mile east of Wester Lairgs, N. 25° E.

East of this line of movement, near the watershed between the Nairn and the Findhorn, conclusive evidence has been obtained of the northerly flow of the ice that radiated from the lofty plateau at the head of the Findhorn. On Beinn nan Cailleach—a hill about three miles south-west of Moy Hall—the quartz-schists on the north-west slope, between the 1,500-feet and 1,750-feet contour lines, are finely glaciated. Striæ are readily found, and they point in one uniform direction—N. 12°–21° W. Along the western margin of the high ground, between Meall More and Creagan Bad Each already referred to, several instances of cross-hatches have been observed, where the striæ point E.N.E. and N.N.W. The north-easterly movement of the ice in Upper Strath Nairn is further proved by the transport of boulders, notably of muscovite-biotite-gneiss and of different types of Old Red Conglomerate.

Boulder-clay is extensively developed on both sides of the watershed between the Nairn and the Findhorn, as, for example, in the Uisge Dubh (Black Water) above Farr House; in the streams draining the north slope of Beinn nan Cailleach and in the various tributaries of the Findhorn near Tomatin. A notable feature of the boulder-clay sections west of Tomatin is the presence of well-striated blocks of Old Red Sandstone, pointing to the existence of an outlier of that formation at no great distance.

Another interesting development of the Drift deposits in Strath Nairn is the morainic gravels on the east side of the valley near Faillie, where they form a remarkable series of parallel ridges, traceable for upwards of a mile, and enclosing lochans or basins of peat. They are strewn with boulders of muscovite-biotite-gneiss, granite, and Old Red Conglomerate.

Mr. Clough. In the tract of western Inverness-shire around Loch Hourn, mapped last year by MR. CLOUGH, the glacial deposits were found by him to consist chiefly of morainic material and boulder-clay. The latter, usually of a brownish colour, is found far up the mountain corries, as well as at lower levels. No stones foreign to the area surveyed have been noticed either in it or in the morainic detritus.

Near the top of Ladhar Bheinn (3,343 feet), on the south side of Loch Hourn, at heights above 2,800 or 2,900 feet, sharp ridges of considerably weathered rock project at the surface, and present no smoothed, distinctly-glaciated contours. In the high region no pieces of rock were found which could not have been derived from localities close by. There are no boulders of pegmatite, nor of siliceous schist like that *in situ* over a large

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area a few miles to the east. A deposit, consisting chiefly of somewhat angular slabs of the local schist, spreads, however, over a considerable extent of ground to the west and south of the hill top, and reaches nearly to the highest point. This deposit somewhat resembles the scree-material, but the inclination of its surface is in many places quite gentle. Mr. Clough.

Near the top of Beinn na Caillich (2,573 feet) the drift is also of a local character and chiefly composed of slabs of siliceous schist. No pieces of the Ladhar Bheinn schists were noticed, though these rocks cover a great area less than two miles to the east and south-east. On the lower ground around Beinn na Caillich, however, boulders of the Ladhar Bheinn schists, including many pieces of the peculiar rock with hornblende and zoisite, are common, and those which are found in some localities must have been carried in a north-westerly direction.

In the Croulin valley, which descends from Beinn na Caillich, near the mouth of Loch Hourn, two rather extensive stratified deposits, probably of glacial age, have been observed. One of them forms a terrace, or a series of minor terraces, between the 300-feet and the 400-feet contours. Few sections of it are to be seen, but the stratification in some places is nearly horizontal. Perhaps this material was laid down in water that was dammed back by an ice-barrier a little lower down the valley. Another deposit of a more finely bedded character, exposed in an excellent section on the E. side of Croulin burn, between the 800-feet and 900-feet contours, is 80 or 90 feet thick, and is composed of bands of laminated stoneless clay and sand, with other bands containing boulders. The stoneless bands, at least nine in number, vary in thickness from 1 to 12 feet. The bedding is nearly horizontal, but the minor laminæ which compose some of the beds are contorted. The slope of the valley in which this deposit lies is steep, and towards the north.

The part of Barrisdale glen above Ambraigh affords a good example of a U-shaped valley, which has been but little altered since the last glaciation. It contains hardly any alluvium, a great part of its floor being formed of smoothed glaciated rock. The side streams have not cut deep channels, but descend in many places over smooth rock ledges.

In the course of Mr. Harker's further investigations in the Isle of Skye and the neighbouring smaller islands, he has been able to confirm and extend his previous conclusions* relative to the glaciation of that area. He has already pointed out that, while the south-eastern part of Skye was over-ridden by the ice-sheet from the Scottish mainland, the glaciation of the central part of the island has been due wholly to a local ice-cap covering the mountain-district. At the same time the natural radiate outflow from this local centre was greatly modified by the pressure of foreign ice on that half of the circumference facing the mainland, the flow being diverted westwards round the northern and southern borders of the central mountain district. On the north Mr. Harker.

* *Summary of Progress* for 1898, p. 179.

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Mr. Harker. side the line along which the native and foreign ice marched together followed very nearly the coast-line of Skye, trending first N.W. and then more nearly N. The Isle of Scalpay, though divided from Skye only by a narrow sound, thus comes to show considerable difference, exhibiting the phenomena of a district over-ridden by foreign ice. The glacial striæ follow there a general direction without much regard to the form of the ground. There is no "kettle-moraine," and the drift is never thick except in a few sheltered places. Foreign boulders occur, though sparingly, at all altitudes, instead of being limited to near the sea-level, as is the case on the Skye side of the Sound.

It was pointed out in 1898* how the westward diversion of the great ice-stream from Glen Sligachan was clearly proved by following the course of its mid-streamline, indicated by the preponderance of granite boulders in the drift on the right and of gabbro on the left; and this line was shown to curve westward at Sligachan, and run for several miles near the high-road. It does not, however, run on, as might be expected, to Loch Harport and so to the sea; but before reaching Drynoch Lodge turns S.W. and S., and eventually finds an outlet in Loch Eynort, having thus described a semi-circle from Sligachan. Granite boulders from the Red Hills are abundant in the drift of Glen Eynort, with a much smaller proportion of gabbro. Farther N. and N.W. the latter rock is not found, but granite continues to be abundant, and erratics of it occur at all altitudes, *e.g.*, on the summit of Preshal Beg (1,160 feet), near Talisker.

The left wing of the Glen Sligachan ice-stream found its way by Bealach a' Mhaim (1,150 feet) into the upper part of Glen Brittle, where a few granite boulders are still found among the much more abundant basalts and gabbros. Between here and the mountains must therefore have been pent in the whole of the ice from the northern and north-western sides of the Cuillins. The southern part of the district affords quite similar evidence, attesting the great volume of the interior as compared with the exterior ice-drainage. Only at a later stage, when both the Scottish and the insular ice had greatly shrunk, did the flow from the Skye mountains approximate to a radiating disposition.

Ross-shire.

Mr. Peach. The glacial phenomena observed in the district of Eastern Ross-shire, mapped last year by Mr. Peach, are regarded by him as nearly all attributable to the later glaciation. At one part of that period the glacier which flowed down the Blackwater seems to have been so powerful as to overlap the highest watersheds between that valley and the streams flowing into Loch Luichart and the Blackwater itself near Garve; for striæ running S.E., and E.S.E., occur on the crests of Meall na Speirag at a height of more than 2,000 feet, and on Beinn Liath Beg, 1,967 feet, both of these elevations rising upwards of 1,200 feet above the bottom

* *Op. cit.*

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of the valley. Again on Cairn na Dubh Coille, 1,750 feet, which overlooks the valley near its great bend to the south, and rises more than 1,200 feet above the valley, the striæ run right across the top, while the whole ridge and sides of the mountain are strewn with huge blocks of augen-gneiss, many of them several tons in weight. The hill itself is built up of "Moine Schist," while the blocks are derived from the augen-gneiss mass which occupies much lower ground to the north and west. Perhaps the most striking feature of the whole region is the remarkable proof supplied by the distribution of the blocks of augen-gneiss as to the direction of movement of the ice during the later glaciation. Immediately beyond the western junction line between the schists and the augen-gneiss, boulders of the latter rock seem to make up most of the moraine-stuff. This preponderance is probably attributable to the large size of the blocks into which the augen-gneiss breaks compared with those of the schist; at any rate the augen-gneiss boulders are by far the most conspicuous constituents of the moraine heaps. Another item of evidence is thus afforded in favour of the idea that a great part of the moraines found on Highland moors and flat-bottomed valleys represent material that was borne forward either within the ice or beneath it, since nowhere in the valley does the augen-gneiss rise into any conspicuous crag above the general level of the ground. That the movement has been generally down the valley admits of no doubt, for, as already stated, from the area of the augen-gneiss innumerable boulders of that material can be followed as a trail right across the low ground and the Cromarty Firth into the Black Isle.* Mr. Peach

A few small boulders of augen-gneiss were found in the moraine-stuff to the west of Alt Guid, and even as far as Glasgamich, while Mr. Gunn has found them to occur within the watershed of the Broom, still further to the west.† These may have been originally borne westwards by the ice during the period of maximum glaciation, and redistributed by the glaciers of the later glaciation. It has been shown that to the north of the area in question, the ice-shed during the period of maximum glaciation lay far to the east of the present watershed. If this is the explanation of the apparently anomalous disposition of these boulders, they afford the only evidence of the earlier or maximum glaciation in the area.

The glacial phenomena in the higher parts of Strathconon and its tributary valleys have been found to be not so striking as those displayed where the valleys debouch on the low ground, as was described in the last *Summary of Progress*. The striæ found on the ridge immediately north of Strathconon indicate a south-easterly movement of the ice across the ground between Strath Bran and Strathconon, but on passing into the latter glen they are deflected to the eastward, and follow the trend of the valley.

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* *Summary of Progress* for 1898, pp. 175–177.

† *Annual Report* for 1896, p. 18.

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Mr. Peach. Very large perched masses of schist, gneiss, and amphibolite are met with at heights of upwards of 2,000 feet on the watershed between Strathconon and Glen Orrin. These indicate an earlier movement of the ice across the present valley-system. To this phase must also be assigned the thick deposit of hard grey till found on the higher hill slopes above the limits of the morainic deposit, and even passing over cols nearly 2,000 feet in height.

CAITHNESS.

Messrs. Peach and Crampton. During the progress of the mapping in Caithness, attention has been given to the remarkably interesting glacial deposits of this county. The lowest and oldest of these deposits has been found in the area surveyed last year by MR. PEACH and MR. CRAMPTON, to be a compact, hard, sandy, dark till with well-glaciated boulders, a large proportion of which are foreign to Caithness. This till, well-known as the Caithness shelly Boulder-clay, is specially characterised by its abundant marine shells. These for the most part are so much shattered and glaciated that they can only be regarded as part of the transported material. The deposit is found in the hollows over the whole area mapped, and often attains a considerable depth. The latest observations of the Geological Survey confirm the conclusions arrived at by previous observers,* that the Caithness till was formed by land-ice, which, after traversing what is now the Moray Firth, crossed the plain of Caithness, in a direction locally varying from W.N.W. to N.W. Numerous instances of striæ were noted last year having this general direction, and boulders of the "Sarclet Conglomerate," a local rock, and the augen-gneiss of Inchbae, in Ross-shire, were traced across the area in trains having the same average trend. Boulders of fossiliferous secondary rocks like those of the Moray Firth Basin, and numerous shell fragments were obtained, but none new to the lists already recorded.†

Overlying the shelly Boulder-Clay where it occurs and overlapping from it on the flagstones, there appears in the eastern part of the area a glacial deposit which varies in colour and in contents according to the local changes in the flagstones. The interstitial clay between the stones is not well compacted, and the included blocks, generally larger than in the older deposit, and mostly of local derivation, are often unglaciated and arranged more or less in lines. Sometimes the deposit is a pell-mell accumulation of flagstone fragments with little or no enveloping matrix. Where the deposit rests on the shelly Boulder-clay the latter usually exhibits an eroded surface, and in certain areas a deposit of sand and gravel intervenes. Shell-fragments and foreign boulders, sometimes found in the lower

* These observations are summarised in a paper read by MESSRS. PEACH & HORNE, *Proc. Roy. Phys. Soc.*, Edin., vol. vi. (1881), pp. 316-352.

† *Loc. cit.*, pp. 339-343.

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layers of the newer deposit, are evidently derived from the older. Where this type of material appears, moraine-mounds also present themselves in such an arrangement as to show that the ice which produced them radiated from certain local centres within the county. In the eastern part of the area a combined glacier emanating from the valley of the River Wick and the Haster Burn seems to have reached the sea in the neighbourhood of Wick and Sinclair's Bay, leaving the low ground studded with its moraines and kames of retreat. It has also had a considerable influence in determining the course of the River Wick, for it made the water to flow round the end of the ice during a pause in its retreat, so that the present small gorge through which the river flows about 1½ mile above Wick is cut on the hillside instead of across a lower elevation a little to the south. This glacier has similarly affected the course of the river between Bilbster and Watten, while the Lochs of Watten, Windlass, and Kilminster seem to lie in hollows dammed up by its moraines. Messrs. Peach and Crampton.

In the western part of the area moraines were observed in such positions as to indicate two local glacier-centres. One of these is Spittal Hill, 577 feet high, a little more than 2 miles S.S.E. from Georgemas Junction. Three hollows that hardly deserve the name of valleys radiate from this hill. In the one opening to the north-west a series of rampart-like moraines crosses the main road near Milton Park or Baumskirk House. Across the hollow that trends to the north-east a fine collection of terminal moraines is arranged concentrically. These are well seen from the main road between the Old Hall of Dunn and the road leading down to Bower Station. Good sections of these mounds have been laid open in quarries near the Smithy of Dunn. Near Achnamoin, across the hollow that opens to the south, moraines again occur.

Another local centre further to the north is formed by the Olrig Hill, which rises to a height of 463 feet as a wide elevation about four miles long from north to south, and 3 miles broad. That this comparatively low hill has actually nourished glaciers in seven valleys that radiate from it, seems to be proved by the moraines, often concentrically arranged, which are found at the mouths of these valleys.

A sufficiently large area of Caithness has not yet been mapped to show the extent of this local glaciation, for the phenomena here reported are mostly attributable to the period of shrinkage of the ice. That the local glaciers extended further seaward than the present coast is proved by the occurrence of their deposits in isolated positions on the top of sea stacks, both near Wick and on the coast between Noss Head and Ackergill.

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Recent.

As a rule little opportunity is afforded by the Recent Deposits to chronicle new facts of general interest The following brief notices may serve to show the general nature of the observations made during the past year. They refer to such formations as Head, Blown sand, River alluvia, Raised beaches, and Peat-mosses.

Cornwall.

Considerable interest attaches to the deposit known as "Head," which overlies the various formations in the southern non-glaciated tracts of England. It is local in origin, and probably represents the subaërial disintegration of underlying and surrounding rocks during a protracted geological period.

Mr. Wilkinson.

In the district of south-western Cornwall mapped last year by Mr. Wilkinson, Head is found at intervals round the coast, generally hanging on to the cliffs. It frequently rests on a thin layer of stratified sand and gravel possibly belonging to an earlier raised beach. It is well developed to the east of Marazion, where it forms a cliff about 40 ft. high. The stones in this deposit are angular and sub-angular, and are arranged more or less horizontally. They consist chiefly of the rocks on which the Head rests. Where the underlying material is slate (Killas) the fragments of it are arranged in somewhat parallel lines, so as to give the appearance of stratification, massive blocks of granite or greenstone occur when either or both these rocks are in place close at hand, and they are grouped in the same way. The matrix of the Head is a tough clay.

In the tract of southern coast-line recently mapped by Mr. Wilkinson, no large spaces of the present surface are occupied by raised beaches. Occasionally, as just. mentioned, the few feet of stratified material which appears from under the head, may be upraised marine alluvium, and may sometimes extend for a short distance inland under the younger deposit. Other traces of raised beaches may be detected in crevices of the rocky cliffs. The tract between Chyandour and Marazion, north of the railway line, is covered by a deposit of alluvium, under which a foot or two below the surface, the old sea-sand deposits are found.

Western Inverness-shire and Ross-shire.

Mr. Clough.

In the tract between Loch Duich and Loch Hourn, mapped last year, Mr. Clough found portions of the 20-feet raised beach at frequent intervals along the coast, but met with no remains of the higher beaches in that district. Gleann Ghuserein, below Easan Bhuidhe, displays extensive sand and gravel flats, separated by morainic banks and mounds. The margins of the flats sometimes run for considerable distances almost at right angles to the river, and perhaps in most parts they represent,

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not lines of erosion, but sides of hollows which previously existed on the uneven morainic surface, and which have now been filled with river-borne material. Mr. Clough.

At Dornie, on Loch Duich, at the back of the 20-feet raised beach, a deposit of sand and gravel may perhaps represent the 100-feet beach, though the surface is now uneven. Further up Loch Long, besides the 20-feet beach, another terrace appears with its top about the 50-feet contour line. In Bundalloch Glen a fine series of gravel terraces slope nearly with the stream; at the foot of the glen the level of the highest terrace is about 100 feet.

CAITHNESS.

In their survey last year MESSRS. PEACH and CRAMPTON confirmed the observation already made as to the absence of raised beaches in Caithness, though these terraces are so abundant in the next counties to the south. Yet the configuration of the coast is eminently favourable both for their formation and preservation. The only marine alluvium met with last year is that of the present beach, the widest expanse of which occurs in Sinclair's Bay. Messrs. Peach and Crampton.

Terraces of alluvium were mapped along the larger river courses. Agricultural operations have been carried to such an extent that most of the smaller streams are either cut straight, and are now running in ditches, or in underground drains, so that many smaller patches of alluvium are not now easily detected. On the sites of several fresh water lochs, which have been either partially or wholly drained for shell-marl, considerable areas of alluvium have been laid bare. The Loch of Scarmclate has been partially drained, also the Lochs of Kilminster and Windlass. An old lake once situated to the north of Corsback Hill, in the same neighbourhood as Loch Scarmclate, is now represented by a wide sheet of alluvium. Another example, a little above an acre in extent, near the farm of Borgie about a mile E.N.E. of Watten, which was drained for shell-marl, yielded skulls of *Bos longifrons*.

Peat has been once much more generally spread across the county than now. Large peat-mosses have been removed by cultivation and for fuel. The most extensive tracts mapped last year are the mosses of Kilminster, North Watten, and Bilbster. The peat seems to be made up of the same species of plants as now live on the surface. Birch and hazel were the only trees, observed to be embedded in it. A few bushes of birch, alder hazel, willow, and blackthorn, still survive in hollows above Watten, and a small wood of these trees at Scouthall, a mile further up the Acharole Burn, represents a remnant of the woodland which may have covered wide areas of Caithness at no very distant date.

Sand-dunes are still in course of formation over large areas in Sinclair's Bay, near the mouth of the River Wester. By their advance the river has been dammed back at several periods and lagoons have been formed, which in many cases are now

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Messrs. Peach and Crampton.

represented by alluvial flats. The process is still going on and is extending seawards. A "Picts-house" near the mouth of the River Wester is only a few feet above the sea-level. The evidence afforded by the eastern part of the area surveyed by MESSRS. PEACH and CRAMPTON tends to prove that at least this part of Caithness has subsided in recent or post-glacial times. MR. CHARLES JOHNSTONE, of Wick, supplied these observers with examples of shell-marl which was dug out of a bed *in situ* beneath low-water mark at Pulteneytown, when the harbour was being deepened. Peat moss with the stools of trees in the position where they grew, is said to be exposed after storms between tide marks on the shores of Sinclair's Bay, a little to the north of Ackergill.

The characteristic bold precipitous coast-line to which the jointed Caithness Flagstones give rise, is well seen both north and south of Wick, the cliffs being indented by caves and "geos" along the joints and fault lines. That the retreat of the cliff-line is comparatively rapid is shown by the cappings of glacial deposits left isolated upon sea stacks. Some of the cliffs, like those at Noss Head and to the south of the Old Wick, rise suddenly out of comparatively deep water, a fact which seems to point to depression of the land since Glacial times.

II.—PETROGRAPHICAL WORK.

The petrographical investigations required in the Geological Survey involve the microscopical and chemical analysis of rocks. This work for England and Scotland has been carried on in the Jermyn Street Museum, under the general charge of MR. J. J. H. TEALL, who conducts the microscopical examination, while DR. POLLARD undertakes the chemical research. The Irish petrography is in the hands of MR. H. J. SEYMOUR at the Dublin office of the Survey. Recent pressure of work has required that a large number of Scottish rocks which had to be determined for the Memoirs now in course of preparation, but could not be undertaken here, should be sent to MR. SEYMOUR, who has completed the examination of a large number of slides and is engaged in the investigation of others.

(*I.*) *IN THE LONDON OFFICE.*

The total number of sliced rocks added to the petrographical collections at Jermyn Street during the past year is 757. Of these 78 are English, 644 Scottish, and 35 Foreign. The English collection of sliced rocks at the end of last year numbered 3,343, the Scottish 9,322, and the Foreign 486. Six microscopic slides with corresponding specimens, illustrating DR. EVANS' paper on "Mechanically-formed Calcareous Rocks" (*Quart. Journ. Geol. Soc.*, vol. lvi., p. 559, and five slides, without rocks, illustrating MR. COOMÁRA SWÁMY'S paper

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on "Ceylon Rocks and Graphite" (*ibid.*, p. 590), were presented to the foreign collection by the respective authors.

The number of rock specimens gathered by the collectors in Scotland during the past year has been 325, in illustration of the geology of the counties of Banff, Midlothian, Perth, and Ross, and of the island of Arran.

Mr. Teall. Detailed reports on 229 rocks have been furnished by MR. TEALL to the field officers. The petrographical work in connection with the forthcoming Memoir on the North-west Highlands has involved the re-examination of the material collected at various times to illustrate the post-Cambrian igneous rocks and the contact metamorphism produced by them. An outline of these results will be found below.

Dr. Pollard. Chemical analyses of rocks and minerals were conducted in the laboratory of the Survey by DR. POLLARD from January to the middle of July, and from the end of September to the close of the year. During the latter half of July and in August he was engaged in resuming, together with the officers in the field, the examination of the dolomitization of the Carboniferous Limestone of South Wales. Many specimens in illustration of this subject were collected, which, together with those obtained in 1899, it has been impossible as yet to study.

In connection with the re-survey of the South Wales coalfield, it has been determined to institute a series of partial analyses of one or more of the seams in that field, with a view to investigating the causes which have led to the anthracitization of the coal, and thereby estimating, if possible, the area occupied by the steam-coal in the region. For the purposes of this enquiry, which we believe will be of considerable commercial importance as well as scientific interest, a corridor in this building has been specially fitted up with the necessary apparatus.

Among the more important petrographical results obtained at the London office of the Survey during 1900 reference may be made to the researches of MR. TEALL, which have brought to light from the Assynt region a remarkable group of eruptive rocks new to this country and, together with the chemical investigations by DR. POLLARD, have clearly illustrated the interesting succession of metamorphic changes which these rocks and the Tertiary granite of Skye have induced in the surrounding dolomites. A brief account of these researches prepared by MR. TEALL is here given, followed by DR. POLLARD'S account of his chemical investigations into the constitution of the same rocks.

THE MARBLES OF ASSYNT.

Mr. Teall. The re-examination by MR. TEALL of the material collected at various times to illustrate the nature of the post-Cambrian igneous rocks of the North-west of Scotland, and the contact metamorphism produced by them, has led to some interesting results, the details of which will be published in the forthcoming Memoir on that region. A brief summary, however, may be given here.

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Mr. Teall. The igneous rocks are represented by the plutonic mass of Cnoc na Sròine, and by various dykes and sills in Assynt and the neighbouring districts. No connected lavas or effusive rocks of any kind are known. The plutonic mass extends from Ledbeg for about five miles in a south-easterly direction, with an average width of about one mile. Cnoc na Sròine (1,306 feet) forms the culminating point. The dominant rock of this mass is a red granite or syenite, remarkably free from ferro-magnesian or any other darker-coloured constituents. It was described by NICOL as a red felspar porphyry, and by MURCHISON as a syenite. DR. HEDDLE pointed out that true porphyritic structure is absent, and that the rock is mainly composed of red felspar, often much stained and decomposed. The essential constituents of this rock are albite or oligoclase-albite, orthoclase and quartz. The two alkali-felspars are sometimes developed as independent constituents, but are more often intimately intergrown, not unfrequently in the form of micro-perthite. Quartz is not an important constituent of the rocks taken as a whole, and is sometimes absent altogether.

The more acid varieties of the red rocks have affinities with the nordmarkites of PROF. BRÖGGER. Taking the mass as a whole, the quartz-syenites (nordmarkites) appear to shade into quartzless syenites, and these again into nepheline-syenites. A typical nepheline-syenite occurs at the foot of the north slope of Cnoc na Sròine. [Slide No. 3086.] It is a coarse-grained rock, composed of large individuals of nepheline and orthoclase, often measuring half an inch or more across, together with biotite and a little accessory melanite. The occurrence of melanite in this rock shows that the nepheline-syenites are intimately connected with the borolanites, which appear to form a basic border to the plutonic mass of Cnoc na Sròine.

In the paper on Borolanite, by MR. TEALL and MR. HORNE,* attention was called to a peculiar type of rock, mainly composed of large individuals of orthoclase and a blue substance, which is evidently an alteration product. This rock apparently forms a kind of pegmatitic vein in the borolanite, east of Aultnacallagach, and is of special interest in connection with a boulder of true nepheline-syenite-pegmatite, found by MR. HINXMAN on the east slopes of Coul More, about five miles west of Cnoc-na-Sròine, and recently sent up for examination from the Edinburgh Museum. In view of what is now known as to the occurrence of nepheline-syenite in the Cnoc-na-Sròine mass there can be little doubt that the boulder has been locally derived, otherwise it might well have been supposed to have travelled from the Christiania district. This block has been cut up and distributed between the Museum of Science and Art in Edinburgh and the Museum of Practical Geology in London. It measured about $9 \times 5 \times 4$ inches. Its component minerals are orthoclase, nepheline, and ægirine. The individuals of orthoclase are of dull, dark, purplish-grey colour, similar to the orthoclase of the pegmatitic vein above

* *Trans. Roy. Soc. Edin.*, vol. xxxvii. (1892), p. 176.

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referred to, and the cleavage faces sometimes measure three or four inches across. Nepheline also occurs in large masses measuring one or two inches in diameter. There is no strongly marked idiomorphism about either of these constituents. The ægirine occurs in prisms sometimes two or three inches in length by a quarter of an inch in breadth, penetrating both orthoclase and nepheline. It is sharply idiomorphic in the prismatic zone, with development of the orthopinacoids and prismatic faces. This boulder was probably derived from a pegmatitic vein similar to that occurring in the borolanite to the east of Aultnacallagach. Mr. Teall.

The relations of albite and nepheline in the various rocks from the plutonic complex of Cnoc-na-Sròine are of special interest. In the quartzose rocks, only albite is found, and the same is true of some rocks without quartz; but the latter often contain both nepheline or its alteration products and albite. As the nepheline increases the albite diminishes, and finally in the nepheline-syenite only orthoclase and nepheline occur.

The plutonic rocks have been intruded into the Durness dolomites which have been profoundly affected in consequence. These altered rocks now contain calcite, dolomite, brucite, diopside, tremolite, mica, forsterite and serpentine. The minerals here mentioned do not occur together in any one specimen, but are distributed irregularly, so as to give rise to different types of rock. Those varieties which consist essentially of carbonates and brucite, are practically identical with the predazzite of the Tyrol. They are found to the north of Cnoc na Sròine in the neighbourhood of the Ledbeg river. A typical specimen of this variety [No. 9208] is a medium-grained, nearly white rock composed of brucite, calcite, and dolomite. The brucite occurs in fibrous or scaly aggregates, which vary from about 0·1 to over 1 mm. in diameter. The larger grains are mostly rounded in outline, but the smaller ones often give square, triangular and hexagonal sections, which strongly suggest the conclusion that the mineral is a pseudomorph after periclase. The carbonates occur as irregular individuals of a somewhat larger size than the brucite. They consist of calcite and dolomite in about equal proportions. The brucite has been isolated and analysed by Dr. Pollard (page 155).

Rocks mainly composed of calcite and forsterite, with a varying admixture of dolomite, sometimes with none at all, constitute another type. A specimen from Cnoc na Sròine [3099] is a fine-grained, nearly white rock, composed of calcite and forsterite. The latter occurs in more or less rounded grains, which vary in size from about 0·2 up to 1 mm. in diameter; the former in large ophitic plates constituting the matrix in which the grains of forsterite are embedded. The forsterite of this specimen has been isolated and analysed by Dr. Pollard (p. 156). The rocks containing calcite and forsterite pass into ophicalcites by the serpentinization of the latter mineral.

Other varieties consist of carbonates and diopside, with or

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Mr. Teall. without tremolite. In these cases it is especially worthy of note that the tremolite is invariably associated with calcite, whereas the diopside is frequently associated with dolomite. This accords with the view that the rocks in question are altered siliceous dolomites, for the development of tremolite ($CaO,3\,MgO,4\,SiO_2$) in dolomite would naturally be accompanied by the formation of calcite, whereas diopside ($CaO,MgO,2\,SiO_2$) could be formed directly by the simple substitution of SiO_2 for CO_2.

Some exceptional rocks are found in the immediate neighbourhood of the contact with borolanite and augite-syenite in the Ledbeg burn about 500 yards north-east of Ledbeg [9203–9207]. In addition to colourless diopside, mica and carbonates, these rocks contain a green ægirine-augite, identical with that in the augite-syenite. The pyroxene has been isolated from a matrix of calcite and analysed by Dr. Pollard (p. 156). It is aggregated in lumps and patches in a matrix of calcite, either by itself [9203] or in association with the normal colourless diopside [9205]. In the latter case it forms a border to the colourless variety. These peculiar rocks indicate a most intimate blending of the igneous and sedimentary material, accompanied by some interchange of constituents of the kind emphasised by Mr. Johnston Lavis. It is possible to obtain specimens [9206] which show the association of the ægirine-augite with orthoclase in one part and with calcite in another, and the pyroxene-orthoclase aggregate—augite-syenite—shows no sign of chilling at the contact.

The field relations of the marbles of Assynt prove that they are the result of the contact-metamorphism of the "Durness limestone series." This series, as developed at Durness, includes both dolomites and limestones, but in the Assynt district only dolomites have been recognised. The majority of the specimens examined accord with the view that they are metamorphosed dolomites, which contained a variable amount of silica. The development of tremolite, forsterite, and periclase or brucite, in such rocks would naturally be accompanied by dedolomitisation, and as a matter of fact these minerals are always found to be associated with calcite in the rocks under consideration. The general conclusions arrived at as a result of the examination of the marbles of Assynt are—

(1.) That they are mainly altered dolomites and that the alteration has been accompanied by dedolomitisation, due either to the development of magnesian silicates such as tremolite and forsterite, or to the formation of periclase or brucite.

(2) That the ophicalcites are the result of the serpentinisation of the forsterite in the rocks containing that material; and, lastly,

(3) That in the immediate neighbourhood of the contact in Ledbeg Burn there has been a reciprocal action between the igneous magma and the sedimentary rock, giving rise to identical

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pyroxenes in both rocks, such pyroxenes being characterised by a combination of the ægirine and diopside molecules. Mr. Teall.

Similar phenomena are seen in Skye, where the rocks of the Durness series have been marmorized by the Tertiary granite.

The re-examination of the material of the dykes and sills which figure so largely in Sheets 101 and 107, has also led to some interesting results. These belong to two types—dark-coloured hornblende rocks (vogesites), and light-coloured felspathic rocks (telsites). There are also a few intermediate varieties (hornblende-porphyrites), but as a rule the two types are sharply marked. The rocks of the dark melanocratic type are essentially composed of idiomorphic hornblende in a felspathic matrix. As a potash felspar (see DR. POLLARD'S analysis, p. 158) plays an important part in the composition of this matrix, the rocks may be termed vogesites. The specimens of the light-coloured leucocratic type are essentially composed of alkali-felspars and quartz (see analyses, pp. 157–159). Ægirine is sometimes present, and when this is the case (2324) the rocks have decided affinities with the grorudites of PROFESSOR BRÖGGER.

The following analyses were made by DR. POLLARD in connection with the foregoing investigation. A specimen of marble from the neighbourhood of Ledbeg (9208) contained grains of a mineral which appeared to be brucite or hydromagnesite. To settle this point the mineral was isolated by the use of bromoform (diluted with xylol). It remained floating in the liquid of 2·41 sp. gr. 0·2388 gramme was taken for analysis, and the following results were obtained: — Dr. Pollard.

SiO_2	·4
Al_2O_3, Fe_2O_3	1·4
CaO	·8
MgO	66·0
Loss on ignition	31·2
Total	99·8

Calculating the "Loss on Ignition" as water, the ratio of MgO : H_2O = 1 : 1·06.

This leaves no doubt that the mineral is *brucite*.

A green pyroxene was isolated from a specimen [9203] and analysed to see whether, near the junction of the igneous and metamorphic rocks, there had been any inter-action. This point was settled in the affirmative, as will be seen from the following analysis:—

Sp. gr. above 3·28.
·5032 gramme taken for main analysis.
·5 gramme taken for Alkalies.
·329 gramme for FeO.

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Dr. Pollard'

——	——	Molecular Ratios.
SiO_2	53·58	·8871
TiO_2	Trace	
Al_2O_3	1·32	·0129
Fe_2O_3	9·46	·0591
FeO	3·36	·0467
MnO	·31	·0043
CaO	16·82	·3003
MgO	11·67	·2891
K_2O	·20	·0021
Na_2O	3·31	·0533
Li_2O	Trace	
Loss on ignition	·73	·0405 (as H_2O)
	100·76	

Ratio of CaO : MgO = 1·04 : 1.

If we assume the following molecules to be present we have—

$(NaK)_2Fe_2Si_4O_{12}$	25·76
$FeFe_2Si_4O_{12}$	1·76
$FeAl_2SiO_6$	3·03
$CaMgSi_2O_6$	62·73
$(CaMnFe)SiO_3$	5·99
SiO_2	·76
Loss on ignition	·73
	100·76

The olivine mineral was separated from three different specimens and analysed [3099, 6743, 6783]. The mineral from No. 6783 (Skye) was analysed to see if it were a diopside or a forsterite, as it seemed possible that the former might have given rise to serpentines. It was, however, found (as will be seen from the analysis) to be a typical forsterite:—

——	3099.	6743.	6783.
SiO_2	42·2	42·6	41·5
Al_2O_3	·8	1·2	·9
Fe_2O_3*	·5	1·2	1·4
CaO	·3	·6	·3
MgO	57·0	51·2	55·6
Loss on Ign.	·3	3·1	1·2
Total	101·1	99·9	100·9

* All Iron calculated as Fe_2O_3. State of oxidation not determined.

Ratio of	MgO : SiO_2
[3099]	2·02 : 1
[6743]	1·8 : 1
[6783]	2·00 : 1

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A partial analysis was made of Specimen No. 6744 to find the ratio of lime to magnesia with the following results:— Dr. Pollard.

SiO_2	15·96
Al_2O_3	·74
*Fe_2O_3	·70
CaO	32·17
MgO	21·43
Loss on ignition	29·22
Total	100·22

* Calculated as Fe_2O_3. State of oxidation not determined.

This gives the ratio of Lime to Magnesia as 1·08 : 1.

The following analyses of rocks, and felspars isolated from rocks, were made for the description of the rocks to be given in the Memoir on the North West Highlands:—

"Dyke or sill, Cnoc an Droigheim, Assynt, Sutherland, Sheet 107. [2324.] A porphyritic felsite with ægirine allied to grorudite.

The following is Mr. Teall's description (*Geol. Mag.*, 1900, p. 391):—

"The rock is a pale green felsite, with somewhat obscure indications of porphyritic felspars and decided traces of parallel structure. Under the microscope it is seen to be composed of polysynthetic aggregates, representing original porphyritic alkali-felspars, streaks of micro-crystalline quartz (scarce), and a crypto- or micro-crystalline felspathic matrix *crowded with acicular microlites of ægirine.* Similar microlites occur in the polysynthetic aggregates, as they do in the phenocrysts in Professor Brögger's grorudite, but they are far less numerous than in the matrix, where they are often so thickly crowded together as to form a felt-like mass. The larger microlites are green, but the smaller ones are colourless; both show the characteristic optic characters of ægirine when isolated from the felspathic material."

"Crag west of Loch Coire na Meidhe. Phenocrysts of alkali felspar (microperthite) and oligoclase in a felsitic matrix. This is evidently the dyke facies of the syenite magma." [8369.]

—	No. 2324.		No. 8369.	
	—	Mol. Ratios.	—	Mol. Ratios.
SiO_2	75·20	1·2450	76·23	1·2621
TiO_2	·12	·0015	·12	·0015
Al_2O_3	12·65	·1238	12·91	·1263
Fe_2O_3	1·53	·0095	1·46	·0091
FeO	·28	·0039	·27	·0037
MnO	·10	·0014	Trace.	—
CaO	·60	·0107	·16	·0028
MgO	·26	·0064	·10	·0025
K_2O	4·14	·0439	4·03	·0427
Na_2O	5·67	·0913	4·34	·0699
H_2O 105°	·12	·0066	·07	—
H_2O above 105°			·30	·0166
Total	100·67	—	99·99	—

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Dr. Pollard. From these figures we get the following composition for the rocks :—

2324		8369	
$K_2Al_2Si_6O_{16}$	24·54	$K_2Al_2Si_6O_{16}$	23·86
$Na_2Al_2Si_6O_{16}$	42·08	$Na_2Al_2Si_6O_{16}$	36·81
$Na_2Fe_2Si_4O_{12}$	4·41	$CaAl_2Si_2O_8$	·79
SiO_2	28·04	Fe_3O_4	·86
	99·07	SiO_2	35·09
			97·41
Unaccounted for—		Unaccounted for—	
TiO_2	·12	Al_2O_3	1·12
FeO	·28	TiO_2	·12
MnO	·10	Fe_2O_3	·87
MgO	·26	MgO	·10
Na_2O	·12	H_2O	·37
CaO	·60		99·99
H_2O	·12		
	100·67		

The ratio of orthoclase to albite is in

No. 2324 - - - - - - 1 : 1·81
No. 8369 - - - - - - 1 : 1·63

The next analysis was made to determine the composition of the felspathic constituents of Vogesite.

Dyke (Post Cambrian) in thrust limestone, west of Loch Bad nan Calman, Strath Kanaird, Sheet 101 [3069].

The felspar was separated by heavy solution, and the fraction, of sp. gr. between 2·55 and 2·64, analysed with the following results :—

—	—	Mol. Ratios.
SiO_2	61·36	1·0159
TiO_2	·10	·0012
Al_2O_3	15·77	·1543
Fe_2O_3	1·06	·0066
FeO	1·07	·0148
MnO	Trace	
CaO	2·89	·0516
MgO	2·76	·0683
K_2O	6·95	·0737
Na_2O	4·65	·0749
Loss 105°	·28	
Loss above 105°	3·06	1698
Total	99·95	

This would give

$K_2Al_2Si_6O_{16}$	41·19
$Na_2Al_2Si_6O_{16}$	39·45
$CaAl_2Si_2O_8$	1·59
	82·23

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Brought forward - - - - - -	82·23
with the following constituents unaccounted for :—	
SiO_2 - - - - - - - -	6·82
TiO_2 - - - - - - - -	·10
Fe_2O_3 - - - - - - - -	1·06
FeO - - - - - - - -	1·07
CaO - - - - - - - -	2·57
MgO - - - - - - - -	2·76
H_2O above 105° - - - - -	3·06
H_2O at 105° - - - - - -	·28
	99·95

The ratio of orthoclase to albite would hence be :—

1 : 1·014

The powder under the microscope was cloudy, and appeared to contain a chloritic mineral. This probably accounts for the large amount (17·72 per cent.) of constituents not accounted for.

The porphyritic felspar and the matrix were separated by heavy solution from a rock [8370], and analysed. The fraction of sp. gr. between 2·575 and 2·590 was taken for the porphyritic felspar, and that of sp. gr. 2·613 to 2·630, for the matrix. The locality given is —Burn, quarter of a mile north of top of Sgòunan More [8370]. This felsite, found by Mr. Peach, is intrusive in the Lewisian Gneiss. The following is Mr. Teall's description of the rock (*Geol. Mag.*, 1900, p. 391): "It consists of numerous phenocrysts of pink felspar, usually giving rectangular sections, and measuring about a quarter of an inch across, embedded in a compact light grey felsitic matrix. Under the microscope the phenocrysts are seen to consist of intergrowths of albite and orthoclase, similar to those observed in the plutonic mass of Cnoc na Sròine. The ground-mass is a micro- or crypto-crystalline aggregate of alkali felspar containing a few minute ragged prisms of ægirine. A little free quartz is probably present, but cannot be identified with certainty under the microscope. This rock contains much less ægirine than the typical grorudites, and in this respect more closely resembles the lindöites of Professor Brögger."

	Porphyritic Felspar.		Matrix.	
	—	Mol. Ratios.	—	Mol. Ratios.
SiO_2 - -	66·73	1·1050	74·44	1·2325
Al_2O_3 - - -	19·05	·1862	14·72	·1440
Fe_2O_3 - - -	·86	·0054	1·17	·0073
FeO - - -			·17	·0023
CaO - - -	Trace.	—	Trace.	—
K_2O - - -	6·69	·0709	3·99	·0423
Na_2O - - -	6·59	·1072	5·82	·0937
H_2O 105° - -	·17	—	·06	—
H_2O above 105° -	·20	·0111	·26	·0144
Total - -	100·29	—	100·63	—

* Calculated as Fe_2O_3, state of oxidation not determined.

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Dr. Pollard. Calculated from these analyses the following would be the percentage of the felspars respectively:—

Porphyritic Felspars.		Matrix.	
$K_2Al_2Si_6O_{16}$ - -	39·63	$K_2Al_2Si_6O_{16}$ - -	23·64
$Na_2Al_2Si_6O_{16}$ - -	56·41	$Na_2Al_2Si_6O_{16}$ - -	49·36
	96·04	SiO_2 - - -	25·15
			98·15
Unaccounted for—		Unaccounted for—	
SiO_2 - - -	2·19	Al_2O_3 - - -	·82
Al_2O_3 - - -	·83	Fe_2O_3 - - -	1·17
F_2O_3 - - -	·86	FeO - - -	·17
H_2O - - -	·37	H_2O - - -	·32
	100·29		100·63

The ratio of orthoclase to albite works out to—

In Porphyritic Felspars 1 : 1·51
In Matrix - - 1 : 2·21

The porphyritic felspar consists of an intergrowth of orthoclase and albite having, as will be seen from the analysis, the composition of PROF. BRÖGGER'S kryptoperthite (Zeitsch. Kryst. XVI. (1890), p. 529).

From a specimen of Kentallenite obtained by MR. KYNASTON from Alt-an-Sithean, Glen Shira, Argyll (Sheet 45) [8734], the following analysis was made:—

SiO_2 - - - - - - - -	52·09
TiO_2 - - - - - - - -	·73
Fe_2O_3 - - - - - - - -	1·84
Cr_2O_3 - - - - - - - -	·10
Al_2O_3 - - - - - - - -	11·93
FeO - - - - - - - -	7·11
MnO - - - - - - - -	·15
(Co,Ni)O - - - - - - - -	·07
CaO - - - - - - - -	7·84
MgO - - - - - - - -	12·48
K_2O - - - - - - - -	3·01
Na_2O - - - - - - - -	2·04
Li_2O - - - - - - - -	Trace
CO_2 - - - - - - - -	·16
P_2O_5 - - - - - - - -	·34
Cl - - - - - - - -	Trace
H_2O 105° - - - - - - - -	·11
H_2O above 105° - - - - - -	·24
Total - - -	100·24

Sp. gr. 2·94

An analysis has also been made of an ægirine granulite collected by MR. CUNNINGHAM CRAIG from a locality half a mile E.S.E. of Derry Lodge, Aberdeen. (Sheet 65.) The rock has been thus described by MR. TEALL:—"[8217.] Ægirine granulite. Alkali felspar, yellow garnet, ægirine and biotite, with magnetite in

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sharply-defined octahedra, apatite and probably sphene as accessories. The garnet occurs in more or less idiomorphic crystals, and as aggregates. It resembles in colour the pale tints of the melanite of the borolanites. The ægirine is bright green; it can be definitely determined by examining the powder of the rock. The prismatic fragments give nearly straight extinction, and the greatest axis of elasticity is approximately parallel to the long axis of the fragment." Mr. H. J. Seymour.

SiO_2	61·79
TiO_2	·90
Al_2O_3	16·90
Fe_2O_3	3·10
FeO	1·07
MnO	·19
CaO	2·44
MgO	·90
K_2O	6·96
Na_2O	5·26
P_2O_5	·34
H_2O at 105°	·14
H_2O above 105°	·29
Total	100·28

(ii.) *IN THE DUBLIN OFFICE.*

In the Dublin Office of the Survey during the past year 228 rock-slices have been examined and reported on by Mr. Seymour, and 119 new slices were prepared and added to the Irish collection of slides which now numbers 2,470. Besides these, 80 slices already in the collection, which had not been previously determined, were examined and named. Of the 228 slides mentioned above, 113 were from Ireland, and the remaining 115 from various parts of Southern Scotland. Mr. H. J. Seymour.

During the recent revision of the Silurian regions of Ireland, attention has been paid to the igneous rocks there developed, and in the ground to the north of Dublin advantage has been taken of a careful microscopical examination of these rocks to bring the maps up to date in regard to their petrography, as this could be done without much expenditure of time in the field. To the south of Dublin, however, in the counties of Wicklow, Wexford and Waterford, the igneous rocks are abundant and so complicated, that as already stated, it has been judged advisable not at present to attempt an adequate revision of the mapping of them, which would involve much time and labour, more urgently needed for the Drift Survey. The following summary will show the general character of the petrographical work last year in Ireland.

The Irish specimens examined by Mr. Seymour comprised types of the igneous rocks met with in the revision of the Silurian areas. In County Down (Sheet 49), a large number of dykes prove to be lamprophyres of different varieties according to the predominance of one or other of the ferromagnesian minerals, hornblende, augite, or biotite. A pre-

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Mr. H. J. Seymour.

liminary account of these rocks was given in last *Summary of Progress* (p. 181), and an examination of more of them was made during the past year, but without bringing to light any additional facts of importance to which special reference need be made. While the rocks are mainly camptonites and kersantites, with and without augite, they include a few which are basalts and dolerites of Tertiary age.

The specimens examined from County Waterford (Sheets 178 and 179) were found to be generally similar in type to those described in last *Summary of Progress*. They are mainly greyish and greenish felsites, the latter sometimes verging on the trachytic andesites. They are sometimes brecciated, and sometimes contain inclusions of other felsites (xenolithic felsites), but with few exceptions are of little interest. Regarding some of the rocks on the south coast of this county, lately regarded as xenolithic felsites, there seems to be reason, as already stated, to doubt whether the fine-grained compact felsite-like base was in all instances truly molten. So far as can be judged at present, this question applies chiefly to those outcrops which occur in the immediate neighbourhood of undoubtedly pyroclastic material. Several specimens of very compact rocks of this kind collected last year were microscopically examined, with the result that the base itself was found to be fragmental, the rocks being, therefore, fine tuffs or ashes. That the fragmental appearance is not due to brecciation subsequent to consolidation seems evident from the complete absence of any trace of fracture *in situ*, in any of the included pieces of lava. Except where complicated by subsequent crushing, the xenoliths in the xenolithic felsites, which have subsequently been brecciated *in situ*, are generally obviously rounded, corroded, or show reaction borders next the magma in which they are embedded, and are distinct from the angular lapilli in the tuffs. Again, in the xenolithic felsites of the Waterford district, the inclusions are all practically in the same state as regards crystallisation, while those of the tuffs vary much in this respect, some being scoriaceous and glassy, others crystalline. In the case of the very compact types it becomes impossible to determine microscopically whether the base is a devitrified felsite or an extremely fine felsitic ash.

Etching with hydrofluoric acid may possibly reveal characteristic etched figures, serving to discriminate between the two classes of rock, and experiments are in progress with this object in view, the rocks selected being those in which the field-evidence is conclusive as to their origin and nature.

True volcanic tuffs occur both at Dunhill Castle (Sheet 179) and in the district to the north thereof, while agglomerates of volcanic origin occur in the neighbourhood of Cullen Castle, a few miles N. of Tramore. These pyroclastic rocks vary considerably in texture, some being coarse agglomerates, others resembling felsites very closely. The lapilli are mainly acid felsites, some scoriaceous, others perlitic, and others finely crystalline. Tuffs generally similar in character occur, amongst other places, at

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Kilmurrin Bay, Bunmahon Head, Newtown Head, and east of Annestown. The association of these tuffs with andesitic lavas has already been referred to (p. 56). Mr. H. J. Seymour.

The specimens collected from County Wicklow being similar to others already sliced and examined, most of them were readily determinable by mere inspection and comparison. Those which it was found desirable to slice consisted chiefly of compact felsitic-looking rocks, whose precise nature was open to question. Many of these specimens on microscopical examination were proved to be of sedimentary origin, some were cherts, others fine-grained grits and sandstones, all appearing to have been more or less hardened, and thus closely resembling some of the felsites in this area.

Of the 115 slices of Scottish rocks examined during the year, 47 were from the Fifeshire Carboniferous volcanic district, and the remainder (68) from various areas in the Old Red Sandstone and Carboniferous areas of Cantyre,ı Ayrshire, Renfrewshire, Stirlingshire, Peeblesshire,and Roxburghshire (Sheets 12, 17, 25, 30, 31, and 39 of the Geological Survey Map of Scotland). They resembled closely the similar types of rock described by Sir A. Geikie* and Dr. Hatch† from neighbouring localities. The rocks from Fifeshire included specimens of the lavas and tuffs, as well as of the intrusive dykes and bosses in the volcanic necks.

The lavas consist of dolerites and basalts, with and without olivine, usually fairly fresh, and of the ordinary characteristic types. In general the tuffs are made up of fragments of basic rocks, finely crystalline to glassy and vesicular in texture, associated with rather abundant quartz-grains and occasionally with a compact pale-coloured material, probably a very fine ash. Pieces of fossiliferous limestone and shale, and, rarely, sandstone also occur in them, the inclusions showing very little signs of metamorphic action. One of the lapilli in the tuffs [8901] is a medium-grained troctolite, composed of basic plagioclase and olivine, the latter much altered and serpentinised. The examination of the stones in the tuffs shows that they belong to the same types of rock as those forming the intrusive dykes in the necks. The average rock is on the borderland of the limburgites, and others vary on either side from olivine-basalts with very little felspar to limburgites proper without felspar-crystals. The most noticeable feature is the constant presence of olivine and the great scarcity of felspar, only two of the slices examined containing the latter mineral in any quantity. Of these two, one is interesting [8912] as being almost identical with Rosenbusch's "Weiselbergit"‡ (augite porphyrite), so far as the ground is concerned, but in the Scottish rock the augites are the conspicuous phenocrysts, and not the plagioclases.

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* *Trans. Royal Soc. Edin.*, 1880, vol. xxix.. plate xii.

† *Trans. Royal Soc. Edin.*, 1892, vol. xxxvii., pp. 115–126.

‡ Rosenbusch *Mikro. Phys. Massig. Gest.*, p. 501, and plate iv., fig. 1.

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Mr. H. J. Seymour.

The rocks selected for examination from the various counties in Southern Scotland above enumerated fall, with few exceptions, into two main groups—trachytic and basaltic. The latter are of the usual types, varying from dolerites to basalts. All contain olivine or its platy modification known as iddingsite [5934 and 5935] and are generally fresh and unaltered.

The acid rocks also vary but slightly in composition, but are much more weathered, the alteration being apparently of the lateritic type, and due to the oxidation of the iron-bearing constituents.* The majority are trachytes with and without sanidine phenocrysts, and with a base typically trachytic in texture, that is, made of sanidine microlites in lath-shaped sections showing flow-orientation. Ferro-magnesian minerals (augite chiefly) are present in more or less amount, but are now mostly represented by chloritic or limonitic pseudomorphs. Exceptionally some plagioclase occurs [6640 and 6641], the rocks containing also a larger quantity of a ferro-magnesian constituent (altered to chlorite) and appearing to verge on the lamprophyres.

Another and more common variety of the trachytic rocks is that in which the felspar of the ground, instead of being lath-shaped, is stumpy and short in character and often associated with some interstitial quartz, and with little or no ferro-magnesian mineral. These may be styled orthophyres, to which type they closely approximate. Examples occur near the boundary between Renfrew and Ayrshire (Sheet 22). Many of the foregoing rocks are porphyritic the phenocrysts being sanidine. Glomero-porphyritic structure is common [4205, 6629] and in some instances the crystals are bent into curved forms traversed by cracks, but without noticeable displacement of the various parts.

The most interesting specimens of the trachytes examined are those which contain the felspathoid nepheline, and are, therefore, *phonolites*. These rocks, two in number [4505 and 4511], from Skelfield Pen, 8 miles S. of Hawick and Pikethaw Hill, Teviot Head, 13½ miles S. of Hawick, are fairly similar to the phonolite of Traprain Law described by Dr. Hatch.† The nepheline in idiomorphic crystals is in places moulded on the felspars, and is generally closely associated with a green pleochroic soda-pyroxene—ægirine or ægirine-augite. The rocks from the neighbourhood of Stirling Castle [Nos. 6670 and 6672] furnish an interesting example of the formation of a micro-pegmatitic base in an augite-diorite by later intrusion of an acid rock (granophyre). The trachytic rocks have a specific gravity varying from 2·54 [6625] to 2·66 [6645], the average of nine being 2·61. The basalts vary from 2·76 [5935] to 2·95 [4502], the average of four being 2·83.

With reference to the remarks made on p. 56 regarding the occurrence of undoubted tuffs and lavas in the Lower Silurian

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* See *Summary of Progress* for 1899, p. 171.

† *Trans. Roy. Soc. Edin.*, vol. xxxvii. (1892), pp. 115-126.

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rocks of the eastern and southern Irish counties, the following petrographical notes, prepared at the request of the Director-General by MR. SEYMOUR, are here inserted :— Mr. H. J. Seymour.

Notes on the Occurrence of Pyroclastic Rocks and Lavas in the Silurian Series of the East and South of Ireland.

Rocks of pyroclastic origin have been recognised in several localities in counties Waterford, Wicklow, and Wexford, while to the north of Dublin others have been found near Balbriggan, and also a few miles inland from that place. In connection with these volcanic rocks a point of interest which may or may not have special significance is, that their outcrops generally appear near the boundary-lines between the Lower and Upper Silurian formations, a feature specially noticeable in counties Wicklow and Wexford, and to a less extent in the Balbriggan area.

Tuffs and ashes are typically developed at Dunhill, Kilmurrin Cove, Newtown Head, and Bunmahon Head, etc., in Co. Waterford, also at Carrickadagan, Co. Wexford, at Duffcarrick, and Ballymoney Fishery in the same county, and at Balbriggan north of Dublin. Agglomerates and volcanic conglomerates and grits are found inland a few miles north-west from Tramore (neighbourhood of Ballyscanlon Lough, Cullen Castle, &c.), and also in massive beds on the shore near Duffcarrick.

Satisfactory evidence of associated undoubted lavas has as yet been procured only at a few places, especially at Knockmahon on the east side of Bunmahon Bay, at Newtown Head, Ballyscanlon Lough, and in the little bay just W. of Bunmahon Head. North of Dublin, good evidence of the occurrence of lavas may be seen. With the exception of the rocks at Newtown Head, the lavas so far examined by MR. SEYMOUR are all andesitic in character. The principal type is an andesite with small augite-phenocrysts, such as that at Bunmahon Head and at Ballyscanlon Lough. The pyroxene in these rocks is usually much altered, and frequently converted into epidote. The Balbriggan rock is a calc-diabase, without conspicuous phenocrysts, but when these are present the mineral is a plagioclase. All of these rocks show in the field the characteristic "pillow" or ellipsoidal structure, and are intimately associated with sediments or ashes composed of volcanic detritus. The rock at Knockmahon and that just west of Bunmahon Head are overlain conformably by finely-banded ash, which at the last mentioned locality, as already described (p. 57), has found its way down into the cracks between the "pillows" forming a kind of matrix for the ellipsoids of the lava. The rocks at Newtown Head are pale grey felsites interstratified with tuffs and fossiliferous sediments. They are compact types, and often show beautifully developed spherulitic structure. They have been described in detail by MR. COWPER REED.* The tuffs

* *Quart. Journ. Geol. Soc.*, vol. lv., pp. 721 and 763.

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Mr. H. J. Seymour.

and agglomerates which have so far been examined microscopically are on the whole acid in composition. A few appear to be slightly more basic as, for example, the clastic rocks of Kilmurrin Cove, Duffcarrick, Ballymoney Fishery, and the agglomerates of the Ballyscanlon Lough neighbourhood. In these cases, however, the original character and composition are rather obscured owing to secondary shearing effects, and the development of abundant chloritic material, which give the rocks a more basic aspect than perhaps they originally possessed. The tuffs and ashes of Balbriggan are andesitic in composition. As a typical example of an acid tuff, the Dunhill (Co. Waterford) variety may be cited. Under the microscope the ground is seen to be microclastic, of a pale colour and full of very minute dull coloured indeterminable lapilli. The larger fragments contained in it chiefly consist of felsites, along with a good many pieces of black slate and chloritic patches representing altered material, apparently in some cases basic felsite. The smaller lapilli consist of scarce quartz and felspar crystals, the latter almost completely kaolinized, but sometimes showing traces of repeated twinning. The felsitic lapilli occur in all stages of crystallisation; some are devitrified, others glassy, and others again pumiceous. In several instances the more compact varieties show beautifully developed flow and perlitic structures, which are still distinctly seen in spite of secondary devitrification.

The varieties of pyroclastic rocks which seem to be slightly more basic, are in section seen to be very highly altered, and to contain a quantity of secondary chlorite and calcite. Notwithstanding the shearing which some have undergone, their originally fragmental character is very obvious. The presence of pieces of basic felspars, appears to indicate a more basic constitution than that of the typical acid tuffs described above. As examples, the green tuff of Sheep Island, and that of Ballymoney Fishery may be cited. The coarse agglomerates and tuffs of the Ballyscanlon Lough area contain abundant felsitic fragments, and less commonly andesitic lapilli, embedded in a dark green schistose base containing chlorite and epidote

The andesitic tuffs at Balbriggan vary from material composed of basic scoriæ and andesitic lapilli, to fine volcanic grits shading off into, and interbedded with black shaly sediments. Some finer grit bands contain fossils. A variety occurs near the Coast Guard Station composed almost entirely of fragmental plagioclase, being, in fact, a typical crystal-tuff.

III.—PALÆONTOLOGICAL WORK.

The Palæontological determinations required for guiding the field-work of the Geological Survey in England, Wales, and Ireland, are made by the staff of Palæontologists under Mr. E. T. Newton F.R.S., at Jermyn Street; those in Scotland by

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MR. B. N. PEACH, F.R.S., at the Survey Office in Edinburgh. MR. NEWTON and his staff are likewise charged with all the palæontological work connected with the Museum of Practical Geology, while MR. PEACH names and superintends the arrangement of the fossils in the Survey collections which are displayed in the Museum of Science and Art, Edinburgh. In the following pages a brief account will be given of the more important parts of the palæontological work of last year.

i. PALÆONTOLOGICAL DEPARTMENT, LONDON.

The ordinary duties of the officers connected with the maintenance of the collection of fossils in the Museum of Practical Geology, and with the registration of specimens received from the Survey and otherwise, although necessarily making the first and a large demand upon their time, are not of such a nature as to need special mention in this place. Between four and five hundred new specimens have been added to those already exhibited in the Museum, and certain important matters of cleaning and remounting have been done.

The Lower, Middle, and Upper Devonian fossils have undergone a thorough revision by MR. H. A. ALLEN, who has taken advantage of the determinations of the REV. G. F. WHIDBORNE, so far as these have been published by the Palæontographical Society. This series of specimens is of especial value on account of its historic interest, many of the specimens having been collected by R. A. C. GODWIN-AUSTEN, J. W. SALTER, W. PENGELLY, and others, while they include many of the type specimens figured by JOHN PHILLIPS in his "Palæozoic Fossils of Cornwall, Devon, and West Somerset." A Catalogue which has been prepared by MR. ALLEN of all the type and figured specimens from the Devonian rocks contained in this Museum will be found on page 196, and it is hoped will prove useful to workers among these older rocks.

A series of Micrasters from the Upper Chalk has been prepared and mounted in a special case in the Museum to illustrate the remarkable work recently done on this group of fossils by Dr. ARTHUR ROWE,* who has shown the presence of certain characters of the test which gradually change as the organisms are followed from lower to higher stratigraphical horizons. One of these characters is found in the ambulacral areas. Among the forms of *Micraster* in the lowest parts of the Upper Chalk, the median part of each of the ambulacral areas is smooth, as shown in *M. cor-bovis* and *M. Leskei*, species characteristic of the *Holaster planus* zone; in another form, the middle part of the ambulacral area shows the zigzag suture line more or less distinctly, and this character is commonly met with in *M. præcursor* in the same zone, and sometimes in the zone of *M. cor-testudinarium*. In the last-named zone the zigzag suture is most often deeply depressed with oblique

* *Quart. Journ. Geol. Soc.*, vol. lv., p. 494 (1899).

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sides, and the ends of the plates are cushion-like. Micrasters with these and certain other characters, and with the test as wide as it is long, have been called *M. cor-testudinarium*. In the still higher zone of *M. cor-anguinum*, the ambulacral area is less depressed, the zigzag groove becomes almost straight and deeply cut, and the cushions are granulated, characters which are found in the common *Micraster* of these beds, *M. cor-anguinum*. The gradual change from one form to another makes it difficult to describe them in words, but in the Museum is shown a series carefully selected from each of the three zones:—1. *Holaster planus*. 2. *Micraster cor-testudinarium*. 3. *M. cor-anguinum*. The specimens from each of the zones are kept separate, so that the variations within the zone may be seen, as well as the gradual change in passing from lower to higher horizons. Thus the smooth ambulacral area is not found above zone 1. The zigzag line is commonly found in zone 1, and sometimes in zone 2, but rarely if ever in zone 3. The deeply divided area is common in zone 2, but rarer in zones 1 and 3. And, lastly, the straight deeply cut and granulated area is the common form of zone 3, but is rarely if ever met with in zone 2, and never in zone 1.

The determination of the series of specimens collected by MR. LAMPLUGH in 1899 from the trial borings at West Brabourne and Penshurst, and including fossils from several horizons of Cretaceous and Oolitic rocks, has occupied much of DR. KITCHIN'S time during the year, and the work is not yet completed. Numerous other fossils, received from the Survey officers during the year, have also been determined by the palæontologists, and preliminary reports have in certain cases been supplied to the various officers. Carboniferous fossils from the Isle of Man were determined for MR. G. W. LAMPLUGH, and from South Wales for MESSRS. STRAHAN and TIDDEMAN. A number of obscure specimens from Skye, sent by MR. H. B. WOODWARD, are probably of Rhaetic age; and others are more definitely from the Lias and Inferior Oolite. Lias fossils from Leicestershire have been determined for MR. C. FOX-STRANGWAYS; Oxfordian and Corallian specimens from St. Ives, Elsworth, and other localities in the counties of Huntingdon and Cambridge, for MR. C. B. WEDD; Kimmeridge Clay and Wealden fossils from Dover, and Lower Greensand fossils from Midhurst and Pulborough, for MR. LAMPLUGH; also Chalk fossils from several localities for MR. C. E. HAWKINS. A number of Devonian fossils from Devon and Cornwall have been received from MR. W. A. E. USSHER, which as yet have only partly been worked out by MR. NEWTON.

In the *Summary of Progress* for 1899 (p. 133) an account was given of the discovery by MESSRS. PEACH and GUNN of Rhaetic and Lias fossils in a volcanic vent near Shiskine, Arran, and of a fragment of chert from the same ground, which led MR. PEACH to think that Cretaceous rocks also had once extended over this part of Scotland. Additional specimens have since been obtained, which confirm the determination of Rhaetic

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fossils, and careful collecting by MR. MACCONOCHIE has supplied important evidence regarding the occurrence of both Liassic and Cretaceous rocks in the same great vent.

The Lias specimens were nearly all in such a friable condition that it was necessary to harden them with dilute shellac varnish before taking wax impressions, which, reproducing much of the characters of the original fossils, enabled many of them to be specifically determined. About 30 distinct forms have been identified; some of them with more certainty than might have been anticipated. Among these are several small examples of *Ammonites angulatus* and *Gryphæa arcuata*, also *Amberleya acuminata*, *Pleurotomaria tectaria*, *Cardinia Listeri*, *Nuculana Tatei* (*Renevieri*, Tate), *Lima succincta*, &c. Such an assemblage of species points unmistakably to the zone of *A. angulatus;* and none of the forms found militate against the rock being of that age. A further confirmation of this inference is found in the fact that all the specimens seem to have come from one bed only, the little differences in their appearance being almost certainly due to different degrees of decomposition; there is likewise the negative evidence of the absence of characteristic fossils of the *A. planorbis* and *A. Bucklandi* zones.

With regard to the Cretaceous rocks, the presence of which had been so shrewdly suspected by MR. PEACH from the small fragment of chert enclosing obscure Foraminifera, many specimens of hard grey limestone and of fragmentary chert or flint have now been secured. The first piece of the limestone sent to Jermyn Street was sliced for the microscope, and on comparison with sections of Antrim Chalk was found to be like specimens of the latter, in which the whole rock has become saccharoid in character, leaving only faint traces of the organisms, so that it seemed almost certain that the Arran limestone is a similarly altered chalk. Many of the specimens, both of limestone and flint, subsequently collected, showed undoubted organisms, such as sponge-spicules, Foraminifera, &c. A number of sections having been prepared for the microscope, parts of the limestone were found to be unaltered and full of Foraminifera, while some of the flint contained masses of sponge-spicules as well as Foraminifera. The more important fossils noticed were *Inoceramus*-shell (showing prisms), polyzoa, echinoderm-fragments, *Porosphæra globularis*, hexactinellid sponge-fragment, tetractinellid spicules, *Globigerina cretacea*, *Textularia*, &c. That the limestone and flint containing these organisms is of the age of the Chalk seems certain. It may be added that DR G. J. HINDE has been good enough to examine the slides, and agrees that they can only be referred to that formation. A catalogue of types and figured specimens from British Pliocene and Pleistocene strata, preserved in the Museum, has been drawn up by MR. ALLEN, and is printed in the Appendix, p. 182.

On two or three occasions small series of fossils collected during the revision of the Silurian districts in Ireland have been sent to Jermyn Street, and have been reported upon by the

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palæontologists there. One set from Stamullen, Co. Dublin, includes examples of *Monograptus priodon*, and *M. Flemingi*, which show that beds of Tarannon or Wenlock age exist in that locality. Two slabs sent from near Gorey, Wexford, were found to contain graptolites referable to the genus *Dichograptus*, and a specimen probably of *Caryocaris Wrighti*, making it tolerably certain that rocks of Arenig age are present in that area.

The Survey is under obligation to MR. V. M. TURNBULL, who has courteously lent a collection of more than 1,300 specimens of fossils, brought together with much care, from the Silurian rocks in the neighbourhood of Haverfordwest. These fossils will be of much value for the purposes of the future re-survey of that district. Their specific determination is therefore desirable, and will shortly be begun.

Assistance has been rendered, as far as possible, to those workers who have wished to examine specimens in the collections of the Museum, or have desired aid in any palæontological work.

Specimens belonging to the Museum have been figured during the year, as shown in the subjoined list:—

Specimens figured in the *Palæontographical Society's* volume for 1900:—

By HENRY WOODS:—

Limopsis albiensis, Woods. Four specimens.
Modiola flagellifera, Forbes.
„ *vectiensis*, Woods.
Septifer lineatus, Sow. Five specimens.
Trigonia dunscombensis, Lycett.
„ *ornata*, d'Orb.

By DR. WHEELTON HIND:—

Sanguinolites tricostatus, Portl.
„ *oblongus*, Hind.
„ *plicatus*, Portl. Three specimens.
Allorisma maxima, Portl. Two specimens.
Tellinomorpha jucunda, de Kon.
Solenomya primæva, Portl.
„ *excisa*, de Kon.
Solenopsis minor, M'Coy.
Conocardium rostratum, Martin.
„ *hibernicum*, Sow. Two specimens.
„ *decussatum*, Etheridge, jnr.
„ *alatum*, de Kon.
„ *aliforme*, Sow.
„ *Koninckı*, Baily.

Besides the above, the following have been figured:—

By F. A. BATHER, "Geological Magazine," May, 1900, pl. viii-x, p. 193:—
Edrioaster buchianus, Forbes.

By DR. WHEELTON HIND, "Quart. Journ. Geol. Soc.," vol. lvi., 1900, p. 47:—
Palæoneilo carbonifera, W. Hind.

By E. T. NEWTON, "Proc. Geologists' Assoc." vol. xvi., 1900, p. 496:—
A remarkable bone from the chalk of Cuxton, possibly referable to the *Rhynchocephalia*.

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By A. C. SEWARD, "Trans. Royal Soc. Edinburgh," vol. xxxix., 1900, part 4, No. 34, pl. 1, f. 1, p. 907 :—

Lepidophloios Harcourtii ? Witham.

ii. PALÆONTOLOGICAL WORK IN SCOTLAND.

In Scotland, the palaeontological requirements of the Survey are performed by MR. B. N. PEACH, Acting Palaeontologist, with the assistance of MR. A. MACCONOCHIE and MR. D. TAIT. The total number of specimens of fossils collected last year was 929. These were entered in the list-books and added to the collections. MR. MACCONOCHIE obtained 121 fossils from the Lower Cambrian rocks of Ross-shire; 26 from the Lower Old Red Sandstone of Arran; 5 from the Upper Old Red Sandstone, and 242 from the Calciferous Sandstone of Berwickshire; and in the remarkable volcanic vent of probably older Tertiary age in Arran, he collected 69 fossils from included masses of Rhaetic beds, 129 belonging to the Lower Lias, and 57 from blocks of limestone which, as above shown, are Upper Cretaceous. MR. TAIT collected 51 specimens from the Ludlow, and 169 from the Downtonian rocks of Lanarkshire; 6 from the Lower Old Red Sandstone of Lorne; 6 from the Upper Old Red Sandstone of Fife, and 8 from the Lower Carboniferous rocks of Edinburgh. MESSRS. PEACH and CRAMPTON, while carrying on their work in Caithness, gathered 40 specimens of fossil fishes from the Caithness flagstone series.

MR. PEACH has determined 365 specimens of fossils from the Lower Cambrian rocks of Skye, 872 specimens from the Lower Carboniferous rocks of East Fife, and 200 specimens from the Carboniferous rocks of Arran. DR. CRAMPTON, acting under MR. PEACH, has named 560 specimens from the Lower Carboniferous rocks of Arran.

MR. PEACH, as usual, has made a preliminary examination of the fossils gathered during the year, and with the assistance of MR. TAIT, has distributed certain groups among specialists for determination. The secondary fossils have been sent to MR. E. T. NEWTON at the Jermyn Street Museum; the fossil fishes to DR. TRAQUAIR; the plants to MR. KIDSTON; the ostracods to MR. KIKRBY, and the lamellibranchs to DR. WHEELTON HIND. With the assistance of MR. TAIT, he has also selected and sent to DR. WHEELTON HIND a large suite of Carboniferous lamellibranchs from the Scottish collections for study for his monograph on that group.

During the year, Dr. TRAQUAIR has named on behalf of the Survey, 146 fossil fishes from the Downtonian rocks, 180 from the Old Red Sandstone, and 101 from the Carboniferous rocks of Scotland. DR. WHEELTON HIND has determined 1,663 lamellibranchs from the Lower Carboniferous rocks of Fife. MR. KIDSTON has named 90 specimens of plants from the Lower Carboniferous rocks of Arran and Fife. Thus, excluding 255 Secondary fossils sent to MR. NEWTON for examination,

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4,177 fossils were determined for the Geological Survey of Scotland during the year.

The following notes of the more interesting or important features of the palæontological work of the Survey in Scotland last year have been supplied by MR. PEACH.

Cambrian.—A further search was made by MR. MACCONOCHIE in the Lower Cambrian rocks of Ross-shire, at the locality on Meall a Ghubhais, near Kinlochewe, where he had obtained the specimens of *Olenellus* described in 1894.* The additional specimens obtained by him, however, add little to our previous knowledge, beyond the fact that the fossils of the *Olenellus*-zone are found to include a small brachiopod *Kutorgina labradorica*—a form described by BILLINGS from this zone in America. They comprise several specimens of *Olenellus Lapworthi*, *O. reticulatus*, *Olenelloides armatus*, and larval forms of *Olenellus*.

Upper Silurian.—The Upper Silurian inlier of Lesmahagow, in Lanarkshire, was again searched last year by MR. TAIT. In the last *Summary of Progress* mention was made of the discovery of *Birkenia elegans* in the Ludlow "Ceratiocaris Bed" at Shanks Castle, Logan Water; but the specimen reported on was from a quarried fragment which was not actually obtained directly from its native bed. The latest explorations, however have supplied several specimens from a band *in situ*. The same band has furnished a specimen of *Thelodus scoticus* which exhibits the eye spots, a new point in the anatomy of this form, as shown in the account given on page 175 by DR. TRAQUAIR. MR. TAIT also found there the chain of rounded, sponge-like bodies which is so common a feature of the Downtonian fish-beds.† On the same horizon MR. FRANK WHITE, of Muirkirk, a local collector, obtained a fine specimen of *Thelodus scoticus* from shales, where it is associated with *Ceratiocaris* at Linn Burn, near the head of Greenock Water, in the Muirkirk district of Ayrshire.

Fishes from two new localities in the Downtonian beds of this inlier were likewise collected by MR. TAIT, one in the Birkenhead Burn, the other at South Field Farm, near Strathavon, where a specimen of *Ateleaspis tessellata* was found, which, as DR. TRAQUAIR shows, has thrown additional light on the structure and affinities of this form. Another feature of MR. TAIT'S recent field-work has been the detection of a band with *Glauconome* occupying a position above the two fish-beds of the Downtonian series in Birkenhead Burn and at Seggholm, along the margin of the Lesmahagow inlier. The stratigraphical succession in this district is thus brought into unison with that which had already been found in the Hagshaw inlier to the south.‡ The remarkable success which has rewarded these latest explorations by the Fossil collector, especially in the newly-discovered locality for

* *Quart. Journ. Geol. Soc.*, vol. l., pp. 661–675, plates xxix–xxxii.

† *Summary of Progress*, 1898, p. 65.

‡ "Silurian Rocks of Scotland," in *Mem. Geol. Survey*, p. 585.

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Downtonian fishes near Strathavon, would warrant a further opening up of the strata at this point as well as a renewed examination of some of the places already worked.

Old Red Sandstone.—With a view of following up the discovery of ostracods in the Lower Old Red Sandstone of Lorne, announced last year,* MR. TAIT again made search in the strata of this age, exposed in the railway cutting about a mile from Oban; but the material obtained by him threw no further light on what had previously been ascertained.

MR. MACCONOCHIE, under MR. GUNN'S direction, collected some specimens from the Lower Old Red Sandstone of Arran, in the western part of the island near Dougrie, and from the shore north of Corrie, but he was only able to obtain a few specimen of worm tracks sufficient to prove that the strata were fossiliferous.

Preparatory to the publication of the Memoir on Central and Western Fife and Kinrosshire by the Director-General, MR. TAIT collected a number of specimens from the Upper Old Red Sandstone of the "Howe of Fife," and obtained *Holoptychius nobilissimus*, both from localities whence it had been formerly collected, and also from some new places.

Carboniferous.—The examination by MR. KIDSTON of the plants from the Calciferous Sandstones of the Eastern Borders in the collection of the Geological Survey of Scotland, proved that these strata, which occupy a low horizon in the Calciferous Sandstone group, enclose a peculiar and little-known flora. As a further knowledge of these plants was highly desirable, MR. MACCONOCHIE was sent to obtain additional specimens from certain places which had formerly been successfully examined. MR. KIDSTON, who joined in this search, has been so good as to supply the notes of the results, which will be found on p. .

Along with the plant remains from Lennel Braes on the Tweed, near Coldstream, a locality rendered famous by its fossil trees, and from sections on the Whiteadder, near Dunse, MR. MACCONOCHIE unearthed the remains of several air-breathing land-animals. Of these, some belong to the genus *Eoscorpius*, one specimen of which represents the trunk and tail of a large species. Several specimens of millepedes were also found. One of these, belonging to the genus *Archidesmus*, shows the head and several of the anterior segments in excellent preservation. Two other forms were also met with, one belonging to the genus *Archiulus* and the other to *Euphoberia*. A large comb-like organ of *Glyptoscorpius* is in the collection recently made, which likewise includes several specimens of the higher crustacea, belonging to the genus *Anthrapalaemon*, as well as other forms new to science. The great success which has attended these latest explorations indicates that it is from these low and least-known horizons of the Carboniferous system, as developed on the Borders, that the greatest amount of new material is likely to be procured.

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* *Summary of Progress*, 1899, pp. 96 and 186.

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In view of the forthcoming Memoirs on East Fife and on Arran, a large suite of Carboniferous fossils has been named by MR. PEACH, assisted by DR. CRAMPTON. DR. TRAQUAIR has kindly named the fishes, DR. WHEELTON HIND has examined the lamellibranchs, MR. KIDSTON the plants, and MR. KIRKBY the ostracods.

Note on Carboniferous Plants from Berwickshire. By R. Kidston, Esq., F.R.S.E.

"At the well-known section on the Tweed at Lennel Braes near Coldstream, the following species of plants were observed:—

Alcicornopteris convoluta, Kidston.
Sphenopteris patentissima, Ett. sp.
Lepidodendron sp.
Stigmaria ficoides, Sternb. sp.
Stigmaria ficoides, var. *undulata*, Göpp.

"From the right bank of the river Whitcadder, one-fourth mile west of Edrom House, the following were collected:—

Marchantites, n. sp.
Alcicornopteris convoluta, Kidston.
Sphenopteris sp.
Aphlebia sp.
Lepidodendron sp.

"From the right bank of Whitcadder, three-fourths of a mile below Allanton:—

Marchantites, n. sp.
Aneimites sp.
Sphenopteris elegans, Brongt.
Alcicornopteris convoluta, Kidston.
Aphlebia sp.
Lepidodendron spitsbergense, Nathorst.
Lepidostrobus sp.
Stigmaria ficoides, Sternb. sp.
Cardiocarpus bicaudatus, Kidston.

"A few specimens still await examination, and among these some stems showing structure, from a road-cutting on the north side of Norham Bridge, from Langton Burn, near Duns, and from Lennel Braes. There are also a few specimens from other localities still unexamined.

"Some of these plants discovered in Berwickshire by MR. MACCONOCHIE are of very great interest. *Lepidodendron spitsbergense* is represented by a fine series of specimens, and though I possess specimens of this plant from other localities in Scotland, I am inbebted to the Berwickshire specimens for characters which clearly show that this species is distinct from *Lepidodendron veltheimianum*, Sternb., of which I previously thought it might be a variety.

"The specimen of *Aneimites*, though small, is the first evidence of this genus in British rocks.

"Perhaps the most interesting fossil amongst the plant impressions collected is the new species of *Marchantites*, a genus

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which I believe has not been previously found in Carboniferous rocks. The similarity of this fossil to certain recent Liverworts is most striking.

"The specimens showing structure have only been partially examined, but are of great interest, as they come from a horizon so low in the Calciferous Sandstone series. They comprise stems of lycopods land fern petioles. Some of the specimens are well preserved, though others are not in so satisfactory a state of preservation. Only a preliminary examination of this material has been made, but the majority of the plants from Norham Bridge and Langton Burn appear to belong to undescribed species."

Note on Fossil Fishes from the Silurian Rocks of the Lesmahagow District.

By Dr. R. H. Traquair, F.R.S.

"Among the specimens of fishes collected last spring by MR. TAIT in the Ludlow and Downtonian beds of the Lesmahagow District and submitted to me by the Director-General for examination are several which are of very special interest.

"In the first instance, two specimens of Coelolepidæ, one a *Thelodus scoticus* from the Ludlow beds at Shanks Castle, the other a *Lanarkia horrida* from the Downtonian of Birkenhead Burn, show a distinct dark spot on each side of the head near the anterior margin, in a position analogous to that of the orbit in *Pteraspis*, and of the supposed orbit in *Drepanaspis*. If these dark spots, as seems probable, represent the position of the eyes in the Coelolepidæ, their interest from a zoological point of view is obvious.

"A number of additional specimens of the rare and hitherto imperfectly known *Ateleaspis tessellata* have been found, which throw much light on the systematic position of this remarkable genus. The presence of a pair of orbits in the middle of the top of the head, feebly indicated in one of the original specimens, is amply confirmed; a small dorsal fin, situated far back, is likewise seen, and the caudal is shown to be heterocercal, but not bilobate. The affinity of the Ateleaspidæ with the Cephalaspidæ is thus brought out still more strongly than before, but the head-shield is still devoid of cornua, and the general form of the anterior part of the creature reminds us of that in the Coelolepidæ.

"Two additional specimens of *Lasanius problematicus* have occurred in which indications of the soft parts are preserved, and which confirm the observations which I have previously made in this subject in my Memoir on these fishes in the *Transactions of the Royal Society of Edinburgh* for 1899. In that Memoir I figured two small round markings in the front of the head of *L. armatus*, but attached no significance or importance to them, and it is therefore interesting to find that these markings reappear in one of the present specimens of *L. problematicus*, and conse-

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quently cannot be accidental. That they represent the orbits is the most probable explanation of their presence, and it may here be pointed out that in their position they remind us of the ring-like structures or markings considered by Dr. Smith Woodward to represent orbits in his remarkable new Ostracoderm genus *Euphanerops*, from the Upper Devonian of Canada."

IV.—PRACTICAL APPLICATIONS OF THE WORK OF THE GEOLOGICAL SURVEY.

It is difficult to give an account of the numerous practical applications of the work of the Survey without entering into details which would be inappropriate here. It may be enough to say that, as in previous years, such applications have been numerous, and that they tend to increase as the nature and utility of the operations of the Survey become more widely appreciated. Enquiries for information on geological matters have been made at each of the offices of the Survey in London, Edinburgh, and Dublin. The subjects on which advice or assistance has been sought have embraced such questions as building-stones, limestone, coal, sand for glass-making, mining, water-supply, well-sinking, soils, sites for houses, and other matters in which a knowledge of geology is required. Information in response to these enquiries has been given as far as possible, personally or by letter. In addition to private individuals, engineers, and other professional men who have sought advice, reference may be made to enquiries received from various Government Departments, particularly the Local Government Board and the Postmaster-General, as well as the London County Council and Urban and Rural District Councils in different parts of the country.

V.—MAPS, MEMOIRS, SECTIONS, &c., PREPARED OR PUBLISHED DURING 1900.

I.—MAPS.

Much time and thought have been given during the past year to the question of printing the maps of the Geological Survey in colour. Up to the present time all these maps, both on the one-inch and the six-inch scale, are coloured by hand. With the advance of geology and the increase of detail in the mapping of the country, the maps become every year more complicated. It is practically impossible to secure either initial correctness of hand-colouring, or subsequent accuracy of revision of the maps when coloured. Every copy of a sheet must be separately checked, and even after the expenditure of

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much time and labour, mistakes and omissions escape detection. There can be no doubt that the labour and risk of error would be enormously reduced if colour-printing were adopted. An experiment in this direction was made a few years ago with the map of England and Wales on the scale of four miles to one inch, which was originally prepared in a hand-coloured edition. This map was afterwards prepared and is now obtainable in colour-printed form, and its success justifies the expectation that if the other maps of the Survey were produced by colour-printing their sale and public usefulness would be much increased. The question of ascertaining what system of colour-printing would be most suitable for the special needs of the Survey was entrusted to MR. CLEMENT REID, who, after a careful study of Continental and American maps, has devised a scheme which has been submitted to the Director-General of the Ordnance Survey, under whose auspices certain trials have already been made. It is anticipated that a beginning will immediately be started in this important reform, and that one or more sheets of the 1-inch map may perhaps be issued colour-printed before the end of the present year.

Reference may here be made to the display of a mounted copy of the colour-printed map of England and Wales at the Paris Exhibition, for which the International Jury awarded to the Geological Survey a Grand Prix Diploma.

(i.)—ENGLAND AND WALES.

Manuscript coloured copies of the 6-in. sheets and quarter sheets are made from the field-maps, and are deposited in the offices of the Survey for consultation by the public.

Of these the following, 193 in number, have been prepared and deposited in the Jermyn Street Office:—

Berkshire.—16 S.W.
Brecknockshire.—31 S.E.; 32 S.W., S.E.; 33 S.W., S.E.; 34 S.W., S.E.; 35 S.W., S.E.; 36 S.W., S.E.; 37 S.E., N.E.; 38 N.W., N.E., S.W., S.E.; 39 N.W., N.E., S.W., S.E.; 40 N.W., N.E., S.W., S.E.; 41 N.W., N.E., S.W., S.E.; 42 N.W., S.W.; 43 N.W., N.E., S.W., S.E.; 44 N.W., N.E., S.W., S.E.; 45 N.W., N.E., S.W., S.E.; 46 N.W., N.E., S.W., S.E.; 47 N.W., N.E.; 48, N.W.; 50 N.W., N.E.
Buckinghamshire.—40 N.E., S.E.
Cheshire.—46 N.W., S.W., N.E., S.E.; 47 N.W., S.W., S.E.
Cornwall.—30 N.W., S.W.; 71 S.E.
Devonshire.—111 N.E.
Dorsetshire.—9 N.W. and S.W., N.E., S.E.; 10 N.W., S.W. and S.E.; 15 N.W., N.E., S.W., S.E.; 16 N.W., N.E., S.W., S.E.; 17 N.W., S.W.; 25 N.W., N.E.; 26 N.W., N.E.; 30 S.E.
Glamorganshire.—9, 10, 11, 12, 16, 17, 18, 19, 25, 26, 27, 28, 33, 34, 35, 36, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51 and 52.
Hampshire.—8, 9, 44, 54, 62, 63, 67, 70, 71, 72.
Isle of Man.—1, 2, 3, 4, 7, 8, 9, 10, 11, 12, 13, 14, 15, 17, 18.
Leicestershire.—33 N.W., S.W.; 38 S.E.; 39 S.W., S.E.
Middlesex.—10 S.E.; 15 N.E.; 16 N.W., N.E., S.W.
Monmouthshire.—4, 6, 7, 11, 12, 13, 17, 18, 19, 22, 23, 24, 27, 28, 29, 32, 33, 34, 38.

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Oxfordshire.—47 N.W., S.W.; 49 N.W., N.E., S.E.; 52 N.W., N.E., S.W., S.E.
Rutland.—8 S.E.; 12 N.E.
Staffordshire.—10 N.E.; 25 N.E., S.E.; 26 N.W., S.W.; 32 N.W.
Sussex.—22, 34, 35, 36, 50.
Wiltshire.—72, 77.

One-inch Maps New Series. Published in 1900.

Sheet 187, Huntingdon. One edition with Drift. By A. C. G. CAMERON.

Sheet 203, Bedford. One edition with Drift. By A. C. G. CAMERON.

Sheet 231, Merthyr Tydfil. Two editions, with and without Drift. By A. STRAHAN, W. GIBSON, and T. C. CANTRILL.

Sheet 316, Havant. One edition with Drift. By W. WHITAKER, C. REID, and C. E. HAWKINS.

Ditto, New Edition.

Sheet 232.—Abergavenny, with additions.

The following one-inch New Series Maps are in the hands of the engraver:—123, 261 and 262, 298, and 314.

(ii.)—SCOTLAND.

One-inch Maps.

One sheet of the one-inch map has been published during the past year:—

No. 27, by S. B. WILKINSON, embracing the north part of the Island of Islay, part of Jura, and part of Colonsay.

The following five sheets are far advanced in preparation, viz.:—

Sheet 21, embracing the northern half of the Isle of Arran, the south end of Bute, with the Little Cumbrae and nearly the whole of the Great Cumbrae and parts of the coast of Ayrshire and Cantyre. It is confidently anticipated that this Sheet will be issued during the summer.

Sheet 37, containing the country on both sides of the upper half of Loch Fyne.

Sheet 38, showing the country on either side of Loch Lomond westwards to Glencoe and the Gare Loch and eastwards to Callander and Fintry.

Sheet 55, embracing the Perthshire Highlands from Dalnaspidal to Loch Tay, and from Loch Rannoch to the Spital of Glenshee and Dunkeld.

Sheet 65, containing the portion of the Grampian Mountains and the valley of the Dee from Linns of Dee to below Ballater and from Glen Gairn to Clova.

(ii.)—IRELAND.

Manuscript duplicate copies of the following six-inch maps have been made, and have been deposited in the Dublin office for public reference:—

Co. Carlow - Sheets, 3, 4, 5, and 8.
Co. Tyrone - Sheet 16 and part of Sheets 14 and 15.

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One-inch Maps published in 1900.

The following new editions of one-inch sheets, showing the revision of the Silurian rocks in the north and east of Ireland, have been issued during the past year—viz., Sheets 37, 38, 47, 50, 57, 80, 87, and 90. While the present *Summary* is in preparation two additional sheets, Nos. 67 and 79, have been published. A large number, comprising all the Silurian ground to the north of Dublin, are now with the engraver. Those of the central and south-eastern counties are in course of preparation for the engraver, and will, as far as possible, be published this year.

II.—SECTIONS.

One Sheet of Vertical Sections (No. 83) of shafts in and below the Pennant Grit in the Taff, Aberdare, and Rhondda Fach Valleys, of the South Wales Coal-field, has been published. Two other sections are in the hands of the lithographers. These Sheets of Vertical Sections, which were being printed off in 1899, were unfortunately destroyed by a fire at the printers. They have now been re-drawn and re-engraved, and are nearly ready for issue.

III.—MEMOIRS.

A.—OFFICIAL.

1.—*England and Wales.*

During the year four Memoirs have been published, namely:—

"Summary of Progress of the Geological Survey of the United Kingdom for 1899," pp. 214. Price 1s.

"The Cretaceous Rocks of Britain." Vol. I. The Gault and Upper Greensand of England. By A. J. JUKES-BROWNE, with Contributions by WILLIAM HILL, pp. 499. Price 9s.

"The Geology of the South Wales Coalfield." Part II., the Country around Abergavenny. By AUBREY STRAHAN and WALCOT GIBSON, with Notes by J. R. DAKYNS and PROF. W. W. WATTS, pp. 103. Price 2s.

It is intended that as each District or Sheet of this important region is completed a descriptive account of its geology shall be published as nearly as possible simultaneously with the map. This series of pamphlets will eventually form a detailed and exhaustive Monograph of the South Wales Coalfield.

"The Geology of the Country between Atherstone and Charnwood Forest." By C. FOX-STRANGWAYS, with Notes by PROF. W. W WATTS, pp. 102. Price 2s.

The following Memoirs are in different stages of progress:—

"The Geology of the Isle of Man." By G. W. LAMPLUGH. (*In slip proof.*)

"Guide to the Geology of London." By W. WHITAKER. 6th Edition. (*At the printers.*)

"The Cretaceous Rocks of Britain," Vol. II. A. J. JUKES-BROWNE, with Contributions by WILLIAM HILL. (*At the printers.*)

"The Water Supply of Berkshire." By J. H. BLAKE, with Contributions by WILLIAM WHITAKER. (*In slip proof.*)

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"The Geology of the Country around Exeter." By W. A. E. USSHER, with Notes by J. J. H. TEALL. (*In slip proof.*)
"The Geology of the Country around Southampton." By CLEMENT REID. (*At the printers.*)
"The Geology of the Country around Kingsbridge and Salcombe." By W. A. E. USSHER. (*In preparation.*)
"The Geology of the South Wales Coal-field." Part III., The Country around Cardiff. By A. STRAHAN and T. C. CANTRILL. Part IV., The Country around Pontypridd. By A. STRAHAN, R. H. TIDDEMAN, and W. GIBSON. Part V., The Country around Bridgend. By R. H. TIDDEMAN and T. C. CANTRILL. (*In preparation.*)
"The Geology of the Country around Reading." By J. H. BLAKE. (*In preparation.*)
"The Geology of the Country around Torquay." By W. A. E. USSHER. (*In preparation.*)

2.—*Scotland.*

The Memoir on Central and Western Fife and Kinross, by the DIRECTOR GENERAL, alluded to in last *Summary of Progress* as nearly ready for the printer, has since been published. It forms a volume of viii., 284 pages, and is sold at 5s. 6d.

Other Memoirs are in progress, and some are far advanced. The important Memoir on the North-West Highlands has demanded more time than was anticipated, but it is now almost all written, and it is hoped that it will be published early next year. The Memoir on Eastern Fife, which has been undertaken by the Director General, may possibly be issued by the end of this year. Several Sheet-memoirs are in hand, and every effort is being made to prepare and issue them simultaneously with the Sheets of the map which they describe, or as soon as possible thereafter.

It may be added that in order to furnish material for the illustration of some of these memoirs, MR. ROBERT LUNN, the Clerk in the Edinburgh Office, last year visited the islands of Arran and Cantyre, and took 148 photographs of rock-sections and scenery.

B.—NON-OFFICIAL.

The following is a list of the non-official publications of the members of the staff of the Geological Survey of the United Kingdom during the year 1900 :—

BLAKE, J. H.—"Excursion to Silchester." *Proc. Geol. Assoc.*, vol. xvi., pp. 513-516.
GEIKIE, SIR A.—"De la Co-opération Internationale dans les Investigations Géologiques." *Congrès Géol. Internat. viii^e Session.*
——. "Outlines of Field Geology." 5th Edit.
——. "Elementary Lessons in Physical Geography." 4th Edit.
——. "Primer of Geology." 3rd Edit.
——. "Primer of Physical Geography." 3rd Edit.
——. "Obituary Notice of the Duke of Argyll." *Nature*, vol. lxii., p. 13.
GIBSON, W.—"On Rapid Changes in the Thickness of the Coal Measures in North Staffordshire." Rep. Brit. Assoc. for 1900.
——. "The Upper Coal Measures Surrounding the Margins of the North Staffordshire Coal-fields, and their Bearing on the Extension of the Coal-field to the West." Trans. Inst. Min. Engineers, vol. xx. pp. 73-78.

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GOODCHILD, J. G.—"The Soils of Cumberland.' In Hodgson's "Flora of Cumberland" (*Carlisle*).

——. "Solar Energy in Relation to Ice." Proc. R. Phys. Soc. Edin., vol. xiv., pp. 137-154.

——. "Some Notes on a Rock Allied to Limburgite, near North Berwick." *Ibid.*, pp. 155, 156.

——. "On the Maintenance of the Earth's Internal Heat." *Ibid*, pp. 157, 158.

ALFRED HARKER. — "Notes, Geological and Topographical, on the Cuillin Hills, Skye." *Scottish Mountaineering Club Journ.*, vol. vi., pp. 1-13.

——. "Magnetic Disturbance in the Isle of Skye." Proc. Camb. Phil. Soc., vol. x., pp. 268-278.

——. "Igneous Rock Series and Mixed Igneous Rocks." Journ. of Geol., vol. viii, pp. 389-399.

HILL, J. B., and H. KYNASTON.—"On Kentallenite and its Relation to other Igneous Rocks in Argyllshire." Quart. Journ. Geol. Soc., vol. lvi., pp. 531-557.

JUKES-BROWNE, A. J.—"Note on a Boring through the Chalk and Gault near Dieppe." Geol. Mag., Dec. 4th, vol. vii., pp. 25-28.

KITCHIN, F. L.—[Description of a new Cretaceous *Terebratulina*.] Appendix B in A. W. Rowe, "The Zones of the White Chalk of the English Coast," pt. 1. Proc. Geol. Assoc., vol. xvi., pt. 6, pp. 355-358, pl. viii., figs. 1-5.

——. "Jurassic Fauna of Cutch; The Brachiopoda." Palæontologia Indica, ser. ix., vol. iii., pt. 1, pp. 1-87, pl. i.-xv.

LAMPLUGH, G. W.—"On Some Effects of Earth-movement on the Carboniferous Volcanic Rocks of the Isle of Man." Quart. Journ. Geol. Soc., vol. lvi., pp. 11-22.

——. "Note on the Age of the English Wealden Series." Geol. Mag., Dec. 4, vol. xii., pp. 443-445.

NEWTON, E. T.—"On a remarkable bone from the Chalk of Cuxton, possibly referable to the *Rhynchocephalia*," Appendix to paper by G. E. Dibley. "Zonal Features of the Chalk Pits in the Rochester, Gravesend, and Croydon areas." Proc. Geol. Assoc., vol. xvi., 1900, pp. 496-499.

REID, C.—"Geology of Hampshire." In "Victoria County History." fol. London.

SEYMOUR, H. J.—"On the occurrence of a Blue Amphibole in a Hornblende Kersantite from Co. Down." Geol. Mag., Dec. 4, vol. vii., pp. 257-260.

STRAHAN, A.—"On the Conditions under which the Plants of the Coal Period grew." (Joint discussions, Sections C. and K.) Rep. British Assoc. for 1900 (Bradford).

TEALL, J. J. H.—"The Natural History of Phosphatic Deposits." (Presidential Address.) Proc. Geol. Assoc., vol. xvi., pp. 369-387.

——. "On Nepheline-Syenite and its Associates in the North-West of Scotland." Geol. Mag., Dec. IV., vol. vii., pp., 385-392.

TIDDEMAN, R. H.—"On the Age of the Raised Beach of Southern Britain as seen in Gower." Geol. Mag., Dec. IV., vol. vii., pp. 441-443.

USSHER, W. A. E.—"The Devonian, Carboniferous, and New Red Rocks of West Somerset, Devon, and Cornwall." Proc. Somerset Arch. and Nat. Hist. Soc., vol. xlvi.

WEDD, C. B.—"The Outcrop of the Corallian Limestones of Elsworth and St. Ives." Rep. Brit. Assoc. for 1900 (Bradford).

WOODWARD, H. B.—"A Greywether at South Kensington." Geol. Mag., Dec. IV., vol. vii., pp. 543, 544.

——, A. R. HUNT, and W. A. E. USSHER.—"Excursion to Newton Abbot, Chudleigh, Dartmoor, and Torquay." Proc. Geol. Assoc., vol. xvi. pp. 425-442.

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APPENDIX A.

CATALOGUE of TYPES and FIGURED SPECIMENS from BRITISH PLIOCENE and PLEISTOCENE STRATA preserved in the MUSEUM of PRACTICAL GEOLOGY, London.

By H. A. ALLEN, F.G.S.

Each specimen is entered under the name given to it when first figured. When the author's name is placed in brackets (Phillips), it refers only to the species and not to the genus. The letter **T** indicates that the specimen is the type of the species. The figures in square brackets [7009], correspond to the number in the Museum Register.

The following abbreviations are employed:—

Mem. Geol. Survey: Memoirs of the Geological Survey of the United Kingdom.

Mon. Pal. Soc.: Monograph of the Palæontographical Society, London.

Quart. Journ. Geol. Soc.: Quarterly Journal of the Geological Society of London.

U.F.B.: Upper Freshwater Beds.

PLIOCENE.

PLANTÆ.

Trapa natans, Linnæus.
C. Reid, Mem. Geol. Survey, Pliocene, 1890, p. 168 (Text figure).
Forest Bed. [7362] Mundesley.

ANIMALIA.

HYDROZOA.

Hydractinia circumvestiens, S. Wood.
C. Reid, Mem. Geol. Survey, Pliocene, 1890, p. 40 (Text figure).
Coralline Crag. [7365] Sutton.

ECHINODERMATA.

Brissus scillæ, Agassiz.
E. Forbes, Mon. Pal. Soc., 1852, pl. ii., f. 4., p. 15.
Coralline Crag. [7359] Iken, Suffolk.

Spatangus reginæ, Gray.
E. Forbes, Mon. Pal. Soc., 1852, pl. ii., f. 2, p. 14.
Coralline Crag. [7358] Orford, Suffolk.

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BRYOZOA.

Fascicularia aurantium, M. Edwards.
C. Reid, Mem. Geol. Survey, Pliocene, 1890, p. 20 (Text figure).
Coralline Crag [7366] Suffolk.

LAMELLIBRANCHIATA.

Kellia corbuloides, Philippi.
A. Bell, Trans. R. Geol. Soc., Cornw., vol. xii., 1898, pl. iii., f. 26 *a*, *b*, *c*, p. 163.
Pliocene. [6477] St. Erth, Cornwall.

Pisidium astartoides, Sandberger.
C. Reid, Mem. Geol. Survey, Pliocene, 1890, pl. v., f. 11 *a*, *b*.
Forest Bed (U.F.B.) [C.R. 17] West Runton.

GASTEROPODA.

Columbella erythrostoma, Bonani.
A. Bell, Trans. R. Geol. Soc. Cornw., vol. xii., 1898, pl. i., f. 1, p. 139.
Pliocene. [C.R. 227] St. Erth.

Hydrobia Steini, E. von Martens.
C. Reid, Mem. Geol. Survey., Pliocene, 1890, pl. v., f. 8.
Forest Bed (U.F.B.) [C.R. 13] West Runton.

Limax modioliformis, Sandberger.
C. Reid, Mem. Geol. Survey, Pliocene, 1890, pl. v., f. 6 *a*, *b*.
Forest Bed (U.F.B.) [C.R. 777] West Runton.

Lithoglyphus fuscus, Pfeiffer.
C. Reid, Mem. Geol. Survey, Pliocene, 1890, pl. v. f. 9 *a*, *b*.
Weybourn Crag. [C. R. 1042] East Runton.

Littorina gibbosa, Etheridge and Bell. T.
A. Bell, Trans. R. Geol. Soc. Cornw., vol. xii., 1898, pl. iii., f. 1, p. 154.
Pliocene. [6475] St. Erth.

Nematura runtoniana, Sandberger.
C. Reid, Mem. Geol. Survey, Pliocene, 1890, pl. v., f. 10 *a*, *b*.
Forest Bed (U.F.B.). [C.R. 787] West Runton.

Odostomia magna, Etheridge and Bell. T.
A. Bell, Trans. R. Geol. Soc. Cornw., vol. xii., 1898, pl. ii., f. 15, p. 146.
Pliocene. [6476] St. Erth.

Paludina gibba, Sandberger.
C. Reid, Mem. Geol. Survey, Pliocene, 1890, pl. v., f. 4 *a*, *b*.
Forest Bed (U.F.B.). [C. R. 762] West Runton.

Triton heptagonum (Brocchi).
S. V. Wood, Mon. Pal. Soc., 1848, pl. iv., f. 8, p. 41.
Coralline Crag. [7361] Gedgrave.

Turbo (Senectus) Newtoni, Etheridge and Bell. T.
A. Bell, Trans. R. Geol. Soc. Cornw., vol. xii., 1898, pl. ii., f. 17, p. 155.
Pliocene. [6479] St. Erth.

Valvata fluviatilis, Colbeau.
C. Reid, Mem. Geol. Survey, Pliocene, 1890, pl. v., f. 7 *a*, *b*.
Forest Bed (Derived specimen in Leda Myalis Bed). [C.R. 826] West Runton.

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PISCES.

Abramis brama, Linnæus.
E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xviii., figs. 19, 20, p. 126.
Forest Bed (U.F.B). [C.R. 957] West Runton.

Acanthias vulgaris, Risso.
E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xix, f. 8, p. 131.
Weybourn Crag. [C.R. 981.] East Runton.

Acerina vulgaris ? Cuvier.
E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xviii., f. 9, p. 121.
Forest Bed (U.F.B.). [C.R. 914] West Runton.

Acipenser sp.
E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xix., f. 6, p. 129.
Forest Bed. (King Coll.) [7350] Mundesley.

Anarrhichas lupus, Linnæus.
E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. x.,f. 4 *a*, *b*, p. 91.
Coralline Crag. [2187] Gedgrave.

Carcharodon megalodon, Agassiz.
E. T. Newton, Mem. Geol. Survey,Vert. Pliocene, 1891, pl. ix., f. 13 *a*, *b*, p. 103; C. Reid, Mem. Geol. Survey, Pliocene, 1890, p. 14 (Text figure).
Red Crag. [3100] Foxhall Hall, Suffolk.

Carcharodon Rondeleti, Mueller and Henle.
E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. ix., f. 4 *a*, *b*, p. 104.
Red Crag. [7320] Boyton.

Cetorhinus maximus, Linnæus (Spine of clasper).
E. T. Newton, Mem. Geol. Survey,Vert. Pliocene, 1891, pl. ix., f. 12 *a*, *b*, p. 102.
Red Crag. [7319] Woodbridge.

Chrysophrys ?
E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. x., f. 1, p. 88.
Red Crag. [7284] Woodbridge.
E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. x., figs. 2, 3, p. 88.
Red Crag. [1971] Boyton.

Chrysophrys ? ("Genus doubtful.")
E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xix., f. 12.
Weybourn Crag. [C.R. 981] East Runton.

Esox lucius, Linnæus.
E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xviii., figs. 11, 13. p. 123.
Forest Bed (U.F.B.). [C.R. 525, C.R. 536.] West Runton.
E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xviii., f. 14, p. 123.
Forest Bed. [Blake 4] Kessingland

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Fish scale.
E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed. 1882, pl. xviii., f. 10.
Forest Bed. (King Coll.) [7351] Happisburgh.

Gadus elegans (Koken).
E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. x., f. 16, p. 96.
Coralline Crag. [1007] Sutton.

Gadus luscus, Linnæus.
E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. x., f. 8, p. 94.
Red Crag. [1969] Boyton.

Gadus minutus? Linnæus.
E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. x., figs. 9, 10, 11, p. 95.
Coralline Crag. [7285] Sutton.

Gadus morrhua, Linnæus.
E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xix., f. 4, p. 127.
Forest Bed. [C.R. 594] Trimingham.
E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xix., f. 5, p. 127.
Forest Bed. [C.R. 660] Mundesley.

Gadus pollachius? Linnæus.
E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xviii., f. 24, p. 128.
Weybourn Crag. [C.R. 880] East Runton.

Gadus pseudæglefinus? Newton. T.
E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. x., figs. 6 *a*, *b*, 7, p. 94.
Coralline Crag. [2183, 7286] Gedgrave.

Gadus virens? Linnæus.
E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. x., figs. 13, 14, p. 96.
Coralline Crag. [1007] Sutton.

Galeus canis, Linnæus.
E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xix., f. 7, p. 130.
Weybourn Crag. [C.R. 981] East Runton.
E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. ix., f. 9, p. 102.
Pliocene. [7377] St. Erth.

Leuciscus erythrophthalmus, Linnæus.
E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xviii., f. 18, p. 126.
Forest Bed (U.F.B.). [C.R. 868] Mundesley.

Notidanus gigas, Sismonda.
E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. ix., f. 18, p. 108.
Red Crag. [7357] Butley Marshes, Boyton.

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Odontaspis contortidens, Agassiz.
E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. ix., f. 17 *a*, *b*, p. 107.
Red Crag. [1978] Boyton.

Odontaspis (Lamna) elegans, Agassiz.
E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. ix., f. 16 *a*, *b*, p. 107.
Red Crag. [7293] Suffolk.

Otoliths, probably **gadoid**.
E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed., 1882, pl. xviii., figs. 25, 26, p. 128.
Weybourn Crag. [C.R. 880] East Runton.

Oxyrhina hastalis, Agassiz.
E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. ix. f. 15 *a*, *b*, p. 106.
Red Crag. [2163] Suffolk.

Perca fluviatilis, Linnæus.
E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xviii. f. 7, p. 120.
Forest Bed. [Blake 3] Kessingland.
E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xviii. f. 8, p. 120.
Forest Bed. (King Coll.) [7342] Happisburgh.
E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xviii. figs. 2–6, p. 120.
Forest Bed (U.F.B.). [C.R. 524, C.R. 523, C.R. 519] West Runton.

Platax Woodwardi, Agassiz.
E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xix., f. 1, p. 122.
Forest Bed. (King Coll.) [7353] Norfolk?
E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xix., f. 3, p. 122.
Weybourn Crag. [C.R. 885] Trimingham.

Raja batis, Montagu.
E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xix., f. 9, p. 131.
Weybourn Crag. [C. R. 981] East Runton.

Raja clavata, Linnæus.
E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xix., figs. 10, 11, p. 132.
Weybourn Crag. [C.R. 981] East Runton.
E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. ix., figs. 19, 20, p. 111.
Red Crag. [7291, 7292] Boyton.

Raja sp.
E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. ix., f. 21 *a*, *b*, p. 112.
Coralline Crag. [3196] Gedgrave.

Tinca vulgaris, Cuvier.
E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xviii., f. 23, p. 127.
Forest Bed (U.F.B.) [C.R. 504, C.R. 508] West Runton.

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Amphibia, Reptilia, Aves.

Bufo sp. (Ilium).
E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xvii., f. 8, p. 118.
Forest Bed (U.F.B.). [7340] West Runton.

Triton cristatus, Laur. (Femur).
E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xvii., figs. 9, 9 *a*, p. 119.
Forest Bed (U.F.B.). [7341] West Runton.

Pelias berus, Linnæus (Vertebra).
E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xvii., figs. 6, 6 *a*, *b*, p. 115.
Forest Bed (U.F.B.). [C.R. 956] West Runton.

Diomedia sp. (Ulna).
E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. ix., f. 1, p. 85.
Coralline Crag. [7283] Orford.

Mammalia.

Ailurus anglicus, Dawkins (Tooth).
E. T. Newton, Quart. Journ. Geol. Soc., vol. xlvi., 1890, pl. xviii., f. 9, p. 451; Mem. Geol. Survey, Vert. Pliocene, 1891, pl. i., f. 18, p. 13. p. 13.
Red Crag. [3924] near Boyton.

Antilope? (Cheek teeth).
E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. iii., figs. 2 *a–c*, 3 *a–c*, p. 23.
Red Crag. [3935] Woodbridge.
E. T. Newton, *Ibid.*, 1891, pl. iii., f. 4, p. 23.
Red Crag. [3922] Sutton.
E. T. Newton, *Ibid.*, 1891, pli. ii., f. 5, p. 23.
Red Crag. [3929] Boyton.

Arvicola arvalis, Pallas (Jaw and teeth).
E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xiv., figs. 2–5, p. 88.
Forest Bed. (U.F.B.) [C.R. 951] West Runton.

Arvicola arvalis, Pallas, var. (Cheek teeth .
E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xiv., f. 7, p. 90.
Forest Bed. (U.F.B.) [C.R. 516] West Runton.

Arvicola (Evotomys) glareolus, Schreber (Jaw and teeth).
E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xiv., figs. 1, 1 *a–c*, p. 82.
Forest Bed (U.F.B.). [C.R. 955] West Runton.

Arvicola gregalis (Pallas) (Jaw and teeth).
E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xiv., figs. 6, 6 *a*, p. 90.
Forest Bed (U.F.B.). [C.R. 905] West Runton.

Arvicola (Evotomys) intermedius, Newton (Jaws and teeth). T.
E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xiii. figs. 2–7, p. 83.
Forest Bed (U.F.B.). [C.R. 906, C.R. 514] West Runton.

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Arvicola (Evotomys) intermedius, Newton (Cheek tooth). **T.**
E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xiii., f. 8, p. 83.
Weybourn Crag. [C.R. 886] Trimingham.

Arvicola (Evotomys) intermedius, Newton (Humerus). **T.**
E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xiii., figs. 10, 10 *a*, p. 83.
Forest Bed. [7460] **Kessingland.**

Arvicola sp. (Humerus and ulna).
E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xiv., f. 9.
Forest Bed (Unio Bed). [C.R. 888] Sidestrand.
E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xiv., f. 10.
Forest Bed (U.F.B.). [C.R. 870] West Runton.

Balæna affinis, Owen (Tympanic).
E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. vi., f. 3, p. 58.
Red Crag. [7294] Felixstow.

Balæna (Balænotus) insignis (Van Beneden) (Tympanic).
E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. vi., f. 4, p. 59.
Red Crag. [7295] Woodbridge.

Balæna primigenia, Van Beneden (Tympanic).
E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. vi., f. 2 *a*, *b*, p. 58.
Red Crag. [7356] Woodbridge.

Balæna primigenia, Van Beneden var. **B.**, Lydekker (Tympanic). **T.**
R. Lydekker, Quart. Journ. Geol. Soc., vol. xliii., 1887, pl. ii., figs. 1, 1 *a*, p. 7.
Red Crag. [7355] Woodbridge.

Balænodon physaloides, Owen (Teeth).
E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. vii., f. 2 *a*, *b*, p. 66.
Red Crag. [3044] Suffolk.
E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. vii., f. 3 *a*, *b*, p. 66.
Red Crag. [3931] Woodbridge.

Balænoptera definita (Owen) (Tympanic).
E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. vi., f. 8, p. 61.
Red Crag. [7296] Felixstow.

Balænoptera emarginata (Owen) (Tympanic).
E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. vi. f. 9 *a*, *b*, p. 62.
Red Crag. [2352] Felixstow.

Belemnoziphius compressus, Huxley (Rostrum). **T.**
T. H. Huxley, Quart. Journ. Geol. Soc., vol. xx., 1864, pl. xix., figs A–D, p. 393.
Red Crag. [7278] Blackheath, three miles east of Ipswich.

Bovine (Lower molar).
E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. iii., f. 1, p. 21
Red Crag. [2000] Boyton.

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Canis lupus, Linnæus (Humerus).
E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. iv., figs. 1, 1 *a*, p. 19.
Forest Bed? (King Coll.) [7329] Norfolk?

Capreolus caprea? Gray (Antler).
E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. iv., f. 10, p. 33.
Forest Bed. (King Coll.) [7324] Happisburgh.

Castor europæus, Owen (Jaw).
E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xii., figs. 1-3, p. 78.
Forest Bed (U.F.B.). [C.R. 894] West Runton.

Castor europæus, Owen ($pm_{\overline{4}}$)
E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xii., f. 8, p. 78.
Forest Bed. (King Coll.) [7344] Norfolk?

Castor europæus, Owen. (Tibia).
E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xii., f. 9, p. 78.
Forest Bed (U.F.B.). [C. R. 890] West Runton.

Castor fiber, Linnæus ($pm_{\overline{4}}$).
E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. v., f. 16 *a*, *b*, p. 49.
Red Crag. [3925] Boyton.

Cervus ardeus, Croizet and Jobert (Antler)
E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. iv., f. 6, p. 25.
Norwich Crag. (King Coll.) [92] Thorpe, Norwich.

Cervus carnutorum, Laugel (Antler).
E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. iv., f. 3, p. 26.
Norwich Crag. [7322] Covehithe, Suffolk.

Cervus Dawkinsi, Newton. *Vide* **C. verticornis.**

Cervus etueriarum, (Croizet and Jobert) (Antler).
E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. iv., f. 5, p. 27.
Forest Bed. (King Coll.) [7323] Cromer.

Cervus tetraceros, Mackie (Antler).
E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. iv., f. 2, p. 32.
Forest Bed. [C.R. 973] East Runton.

Cervus verticornis, Dawkins (Antler).
W. Boyd Dawkins, Mon. Pal. Soc., 1887, pl. v., f. 2, p. 22; C. Reid, Mem. Geol. Survey, Pliocene, 1890, p. 183 (text figure 45).
Forest Bed. [7368] Kessingland, Suffolk.

Cervus verticornis, Dawkins (Antler).
W. Boyd Dawkins, Quart. Journ. Geol. Soc., vol. xxviii., 1872, p. 407 (text figure). Described as **Cervus Dawkinsi**, E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, p. 54. Refigured, W. Boyd Dawkins, Mon. Pal. Soc., 1887, pl. ii., f. 1, p. 7.
Forest Bed. (King Coll.) [7321] Norfolk?

Cervus sp., (Cheek teeth.)
E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. iii., figs. 8 *a*, *b*, 9 *a*, *b*, p. 25.
Red Crag. [7309, 7310] Woodbridge and Boyton.

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Cetotherium (Plesiocetus) dubium (v. Beneden) (Tympanic).
E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. vi., f. 10 *a*, *b*, p. 63.
Red Crag. [7316] Felixstow.

Choneziphius planirostris (Cuvier) (Periotic).
R. Lyddeker, Quart. Journ. Geol. Soc., vol. xliii., 1887, pl. ii., f. 7, p. 14; E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. viii., f. 6, p. 69.
Red Crag. [7298] Woodbridge.

Coryphodon (Cheek tooth).
E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. v., f. 12 *a*, *b*, p. 41.
Red Crag. [7287] Woodbridge.

Delphinus (Phocæna) orcoides, Lankester (Tooth).
E. Ray Lankester, Ann. Mag. Nat. Hist., Ser. 3, vol. xiv., 1864, pl. viii., figs. 17, 18, p. 356.
Red Crag. [7305] Woodbridge.

Delphinoid ? (Periotic).
E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. viii., f. 9, p. 80.
Red Crag. [7299] Woodbridge.

Delphinoid. (Periotics).
E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. viii., figs. 10 *a*, *b*, 11 *a*, *b*, 12 *a*, *b*, p. 80.
Red Crag. Figs. 10, Felixstow, 7302; 11, Woodbridge, 7303; 12, Boyton, 7304.

Delphinoid (Right tympanic).
E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. viii., f. 13, p. 80.
Red Crag. [7312] Boyton.

Elephas meridionalis, Nesti (m 3).
A. Leith Adams, Mon. Pal. Soc., 1881, pl. xviii., f. 4, p. 196.
Forest Bed. (King Coll.) [7333] Mundesley.

A. Leith Adams, Mon. Pal. Soc., 1881, pl. xvii., f. 8. (last milk molar).
Forest Bed. (King Coll.) [7332] Cromer.

Equus caballus-fossilis, Rütimeyer (m^2).
E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. vii., figs. 8, 8 *a*, p. 30.
Forest Bed. (King Coll.) [7330] Cromer.

Equus stenonis, Cocchi (m^1 ?).
E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. vii., figs. 10, 10 *a*, p. 35.
Forest Bed. (King Coll.) [7331] Cromer.

Equus stenonis, Cocchi (Cheek tooth).
E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. v., f. 7 *a*, *b*, p. 37.
Norwich Crag. [7314] Thorpe, Norwich.

Eucetus amblyodon, Du Bus (Teeth).
E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. viii., figs. 1, 2, p. 65.
Red Crag. [7317, 7318] Woodbridge.

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Felis ? (Fibula).
E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. iv., figs. 4, 4 *a*, p. 23.
Forest Bed. (King Coll.) [7327] Norfolk ?

Gazella anglica, Newton (Frontal and horn-core). T.
E. T. Newton, Quart. Journ. Geol. Soc., vol. xl., 1884, pl. xiv., figs. 1, 2, 3, 6, p. 280; Mem. Geol. Survey, Vert. Pliocene, 1891, pl. iii., f. 6 *a–c*, p. 23.
Norwich Crag. [7325, 89] Thorpe.

Globicephalus uncidens (Lankester) (Periotic).
E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. viii., f. 8, p. 77. (See also *Delphinus orcoides.*)
Red Crag. [7301] Woodbridge.

Herpetocetus scaldiensis, v. Beneden (Tympanic).
E. T. Newton, Mem. Geol. Survey, Vert Pliocene, 1891, pl. vi., f. 11 *a*, *b*, p. 64.
Red Crag. [7315] Felixstow.

Hipparion gracile (Kaup) (Cheek teeth).
E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. v., f. 8 *a*, *b*, p. 37.
Red Crag. [7313] Woodbridge.
E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. v., f. 9 *a*, *b*, p. 37.
Red Crag. (Baker Coll.) [7307, 7308] Woodbridge.

Hyracotherium leporinum, Owen (Cheek teeth).
E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. v., f. 6, p. 41.
Red Crag. [1991] Boyton.

Martes sylvatica, Nilsson ($m_{\overline{1}}$).
E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. iv., figs. 3, 3 *a*, p. 25.
Forest Bed (U.F.B.) [C.R. 501] West Runton.

Mastodon arvernensis, Croizet and Jobert ($pm_{\overline{4}}$).
C. Reid, Mem. Geol. Survey, Pliocene, 1890, p. 15 (text figure).
Red Crag. [1983] Boyton.

Megaptera affinis (v. Beneden) (Tympanic).
R. Lydekker, Quart. Journ. Geol. Soc., vol. xliii., 1887, pl. ii., figs. 4, 4 *a*, p. 7; E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. vi., f. 6 *a*, *b*, p. 60.
Coralline Crag. [7279] Sudbourn, Suffolk.

Mesoplodon longirostris ? (Cuvier) (Periotic).
R. Lydekker, Quart. Journ. Geol. Soc., vol. xliii., 1887, pl. ii., f. 8, p. 7; E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. viii., f. 7, p. 72.
Red Crag. [7297 Woodbridge.

Mesoplodon scaphoides, Newton (Rostrum). T.
E. T. Newton, Quart. Journ. Geol. Soc., vol. xlvi., 1890, pl. xviii., f. 8 *a*, *b*, p. 450.
Red Crag. [7277] Near Woodbridge.

Mus sylvaticus, Linnæus (Jaw with teeth).
E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xiv., figs. 11, 11 *a*, p. 93.
Forest Bed (U.F.B.). [C.R. 899] West Runton.

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Myogale moschata (Linnæus) (Vertebra).
E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xvi., figs. 4, 4 *a*, *b*, p. 98.
Forest Bed (U.F.B.). [C.R. 909] West Runton.

Orca citoniensis, Capellini (Periotic).
R. Lydekker, Quart. Journ. Geol. Soc., vol. xliii, 1887, pl. ii., f. 3, p. 7; E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. viii., f. 5, p. 76.
Red Crag. [7300] Woodbridge.

Phoca (Radius).
E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. v., figs. 1, 1 *a*, *b*, p. 29.
Forest Bed. [C.R. 875] Wood Hill, Runton.

Physeter macrocephalus, Linnæus (Tooth).
E. T. Newton, Quart. Journ. Geol. Soc., vol. xlii., 1886, pl. xi., figs. 1–4, p. 316; E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. vii., f. 1, p. 65.
Forest Bed. [1500] Sidestrand.

Rhinoceros etruscus, Falconer ($pm\frac{4}{}$).
E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. viii., figs. 6, 6 *a*, p. 38.
Forest Bed. [7335] Pakefield.

Rhinoceros incisivus (Kaup) (up. pm.).
E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. v., f. 1 *a*, *b*, p. 38.
Red Crag. [7289] Woodbridge.

Ruminant, genus ? (Metatarsus).
E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. iii., figs. 7, 7 *a*, *b*, p. 24.
Coralline Crag. [7281, 7282] Gedgrave.

Sorex pygmæus? Pallas (Jaw and teeth).
E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xv., figs. 11, 12, p. 97.
Forest Bed (U.F.B.). [C.R. 953] West Runton.

Sorex vulgaris, Linnæus (Jaws, teeth, humerus, and femur).
E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xv., figs. 5–10 *a*, p. 97.
Forest Bed (U.F.B.). [C.R. 537, C.R. 900, C.R.53] West Runton.

Sus palæochœrus, Kaup ($m\frac{3}{3}$).
E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. iii., f. 13, p. 36.
Red Crag. [7306] Boyton.
E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. iii., f. 14, p. 36.
Red Crag. [7311] Woodbridge.

Sus scrofa ? Linnæus ($m\frac{}{3}$).
E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. ix., f. 3, p. 43.
Forest Bed ? (King Coll.) [7351] Norfolk ?

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Tapirus arvernensis, Devèze and Bouillet (Cheek teeth).
E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. v., f. 10 *a*, *b*, p. 40.
Red Crag. [7288] Woodbridge.
E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. v., f. 11 *a*, *b*, p. 40.
Red Crag. [7290] Boyton.

Trogontherium Cuvieri, Owen. (Maxilla with teeth).
R. Owen, Geol. Magazine, vol. vi., 1869, f. 1, p. 49 (text figure); E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xi., f. 13, p. 65.
Forest Bed. (King Coll.) [7343] Norfolk?

Trogontherium Cuvieri, Owen (pm $\frac{4}{4}$; m $\frac{1}{1}$, $\frac{2}{2}$, $\frac{3}{3}$).
E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xi., f. 8, p. 65.
Forest Bed. [C.R. 492] East of Cromer.

Trogontherium Cuvieri, Owen (pm $\frac{4}{4}$; m $\frac{1}{1}$, $\frac{2}{2}$).
R. Owen, Geol. Magazine, vol. vi., 1869, f. 3, p. 51 (text-figure); E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xi., f. 10, p. 65.
Forest Bed. (King Coll.) [7342] Mundesley.

Trogontherium Cuvieri, Owen (Tibia and fibula).
R. Owen, Geol. Magazine, vol. vi., 1869, pl. iii., figs. 4–7, p. 55; E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xi. figs. 19, 19 *a*, p. 65.
Forest Bed. (King Coll.) [7345] Mundesley.

Tursiops (Delphinus) tursio? (Bonnaterre) (Vertebra).
E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. viii., f. 14 *a*, *b*, p. 80.
Coralline Crag. [C.R. 280] Broom Pit, Gedgrave.

Ursus ferox-fossilis? Busk (Max. and teeth).
E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. i, figs. 5, 5 *a*, p. 11.
Forest Bed. (King Coll). [7328] Mundesley?

Ursus spelæus, Blumenbach (pm $\frac{4}{4}$, m $\frac{3}{3}$.)
E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. ii., figs. 2, 3, p. 11.
Forest Bed. [7337, 7338] Overstrand, Cromer.

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PLEISTOCENE.

PLANTÆ.

Salix repens ? Linnæus.
Oswald Heer, Phil. Trans., vol. 152, 1863, pl. lxxi., f. 6, p. 1081.
Pleistocene. [7367] Bovey Tracey, Devon.

Salix cinerea, Linnæus ; **Salix repens**, Linn. ? ; **Betula nana**, Linn.
Oswald Heer, Phil. Trans., vol. 152, 1863, pl. lxxi., f.1 *a–k*, p. 1080.
Pleistocene. [7360] Bovey Tracey, Devon.

ANIMALIA.

GASTEROPODA.

Fusus longiroster, Brocchi.
G. W. Lamplugh, Mem. Geol. Survey, I. of Man. (*In the press*).
Pleistocene. [7364] Cranstall Pt., I. of Man.

Fusus nov. sp. ? Forbes. T.
Ed. Forbes, "Malacologia monensis," Cat. Mollusca I. of Man (Edin.), 1838, pl. iii., f. 1, p. 60 ; G. W. Lamplugh, Mem. Geol. Survey, I. of Man.
Pleistocene. [7363] North Coast of Isle of Man (washed on shore).

Nassa Kermodei, Kendal.
G. W. Lamplugh, Mem. Geol. Survey, I. of Man.
Pleistocene. [6163] Cranstall Pt., I. of Man.

Nassa monensis, Forbes.
G. W. Lamplugh, Mem. Geol. Survey, I. of Man.
Pleistocene. [6165] Cranstall Pt., I. of Man.

Trophon clathratus, Linnæus.
G. W. Lamplugh, Mem. Geol. Survey, I. of Man.
Pleistocene. [6673] Cranstall Pt., I. of Man.

AVES.

Colymbus septentrionalis, Linnæus (Bones).
E. T. Newton, Geol. Mag., 1883, pl. iii., figs. 1–7 *a*, p. 97.
Pleistocene (Mundesley River Bed). [108] Mundesley.

MAMMALIA.

Elephas antiquus, Falconer (p.m.[2]).
Leith Adams, Mon. Pal. Soc., 1879, pl. xii., figs. 3, 3 *a*, p. 86. (Humerus), Mon. Pal. Soc., 1879, pl. xvi., figs. 6, p. 214, 233.
Pleistocene. (Cotton Coll.) [7369, 7371] Ilford, Essex.

Elephas primigenius, Blumenbach (m [2]).
Leith Adams, Mon. Pal. Soc., 1879, pl. xii., f. 1, p. 106.
Pleistocene. [7373] Crayford.

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Microtus (Arvicola) ratticeps (Key. and Blasius) (Cheek teeth).
E. T. Newton., Geol. Mag., 1890, p. 454, f. 1.
Pleistocene. [3085] Crayford.

E. T. Newton, Geol. Mag., 1890, p. 454, f. 2.
Pleistocene. [5643] Erith.

Mustela robusta, Newton (Skull and lower jaw). T.
E. T. Newton, Quart. Journ. Geol. Soc., vol. lv., 1899, pl. xxviii., figs. 1-3, p. 425.
Pleistocene. [6630] Ightham Fissure, Kent.

Myodes lemmus (Linnæus) (Cheek teeth).
E. T. Newton, Geol. Mag., 1890, p. 454, figs. 7, 8.
Pleistocene. (Spurrell Coll.) [5640] Erith.

Myodes torquatus (Desmarest) (Cheek teeth).
E. T. Newton, Geol. Mag., 1890, p. 454, figs. 3-6.
Pleistocene. (Spurrell Coll.) [5641] Erith.

Spermophilus altaicus, Eversmann (Teeth and bones).
E. T. Newton, Geol. Mag., 1882, pl. ii., figs. 1-13, p. 51.
Pleistocene (Arctic Fresh-water Bed). [6370] Mundesley.

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APPENDIX B.

Catalogue of Types and Figured Specimens from British Devonian Strata preserved in the Museum of Practical Geology, London.

By H. A. Allen, F.G.S.

Each specimen is entered under the name given to it when first figured. When the author's name is placed in brackets, (Phillips), it refers only to the species and not to the genus. The letter **T** indicates that the specimen is the type of the species. The identity of some few specimens is not quite certain: these are marked [**Doubtful**]. The figures in square brackets, [7009], correspond to the number in the Museum Register.

The following abbreviations are employed:—

Trans. Geol. Soc.: Transactions of the Geological Society of London.

Quart. Journ. Geol. Soc.: Quarterly Journal of the Geological Society of London.

Mon. Pal. Soc.: Monograph of the Palæontographical Society London.

Pal. Foss.: Figures and Descriptions of the Palæozoic Fossils of Cornwall, Devon, and West Somerset, by John Phillips, 1841.

ANIMALIA.

Cœlenterata.

Sphæronites tesselatus, Phillips. **T.**

H. T. de la Beche, Trans. Geol. Soc., Ser. 2, vol. iii., 1832, pl. xx., f. 1, p. 164 ("An undescribed fossil"). Refigured J. Phillips, Pal. Foss., pl. lix., f. 49**, p. 135. Refigured as **Sphærospongia tesselata**, G. J. Hinde, Quart. Journ. Geol. Soc., xl., 1884, pl. xxxvii., f. 1, *b c*, p. 135.

Middle Devonian. [7222, 7223] St. Mary Church, Torquay.

Sphærospongia tesselata. *Vide* **Sphæronites.**

Calceola sandalina (Linnæus).

J. Phillips, Pal. Foss., pl. lx., f. 102*, p. 137; Davidson, Mon. Pal. Soc., 1865, pl. xx., f. 13, p. 105.

Middle Devonian. [7086] Chircombe Bridge, Newton.

Pleurodictyum problematicum, Goldfuss.

J. Phillips, Pal. Foss., pl. ix., f. 24 *a*—*c*, p. 19.

Lower Devonian. [6875] Meadfoot, Torquay.

J. Phillips, Pal. Foss., pl. lx., f. 24 *a*, *b*, p. 230.

Middle Devonian. [6934] Ogwell, Newton.

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Strombodes helianthoides, Goldfuss.
J. Phillips, Pal. Foss., pl. v., f. 13 *a*, p. 10.
Middle Devonian. [7084] Mudstone Bay, Devonshire.

Turbinolopsis bina, Lonsdale.
J. Phillips, Pal. Foss., pl. i., f. 2 *b*, *c*, p. 4.
Upper Devonian (Pilton Beds). [7170] Combe, Ashburton, Devon.

Turbinolopsis pluriradialis, var. *α*, Phillips.
J. Phillips, Pal. Foss., pl. ii., f. 5 *a*, *b*, *d*, p. 5.
Upper Devonian (Pilton Beds). [7171] Brushford, N. Devon.

ECHINODERMATA.

Actinocrinus ? Batheri, Whidborne. T.
G. F. Whidborne, Mon. Pal. Soc., 1898, pl. xxxii., figs. 2, 2 *a*, *b*, 3, 3 *a*, *b*, p. 222.
Upper Devonian (Marwood Beds). [7145,7146] Braunton.

Actinocrinus Porteri, Whidborne. T.
G. F. Whidborne, Mon. Pal. Soc., 1898, pl. xxxi., figs. 1, 1 *a*, 2, 5; pl. xxxii., f. 1, p. 220.
Upper Devonian. [7138-7141] North Devon.

Adelocrinus hystrix, Phillips. T.
J. Phillips, Pal. Foss., pl. xvi., f. 42 *a*, *b*, p. 30; G. F. Whidborne Mon. Pal. Soc., 1898, pl. xxx., f. 4, p. 224.
Upper Devonian (Pilton Beds). [7157] Brushford.

G. F. Whidborne, Mon. Pal. Soc., 1898, pl. xxx., figs. 7, 7 *a*, p. 224.
Upper Devonian (Pilton, Beds.) [7156] Braunton, N. Devon.

Cupressocrinus crassus, Goldfuss.
G. F. Whidborne, Mon. Pal. Soc., 1895, pl. xxiv., figs. 4, 4 *a*, p. 207.
Middle Devonian. [7087] Newton Bushel.

Cyathocrinus ? ellipticus, Phillips. T.
J. Phillips, Pal. Foss., pl. xvi., f. 49 *a*—*d*, p. 32.
Upper Devonian. [7147] Petherwin, Cornwall.

Cyathocrinus ? macrodactylus, Phillips,
J. Phillips, Pal. Foss., pl. xv., f. 41*e*, p. 29. Refigured as **Taxocrinus macrodactylus**: G. F. Whidborne, Mon. Pal.Soc., 1898, pl. xxxiii., f. 2, p. 215.
Upper Devonian (Pilton Beds). [7148] Pilton, North Devon.

Eugaster ? perarmatus (Whidborne). T.
G. F. Whidborne, Mon. Pal. Soc., 1898, pl. xxvii., figs. 6, 6*a*, p. 209.
Upper Devonian (Pilton Beds). [7163] Braunton Down.

Hexacrinus depressus, Austin. T.
T. Austin, "Recent and Fossil Crinoidea," 1843, pl. vi., f. 2 *a*—*e*, p. 49.
Middle Devonian. [7089, 7091] Newton Bushel.

Hexacrinus interscapularis (Phillips).
G. F. Whidborne, Mon. Pal. Soc., 1895, pl. xxi., f. 2; pl. xxii., figs. 2, 2*a*, p. 190. (See also *Platycrinus interscapularis*.)
Middle Devonian. [1549, 7090] Bradley and Newton Abbot.

Hexacrinus macrotatus, Austin. T.
T. Austin, "Rec. and Foss. Crinoidea," 1843, pl. vi., figs. 3 *a*, *d*, p. 50.
G. F. Whidborne, Mon. Pal. Soc., 1895, pl. xxii., f. 6, p. 192. (See also *Platycrinus tuberculatus* ?)
Middle Devonian. [6880] Newton Bushel.

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Hexacrinus melo. *Vide* **Platycrinus interscapularis.**

Hexacrinus ? pentangularis, Austin. **T.**
T. Austin, "Rec. and Foss. Crinoidea," 1843, pl. vii., figs. 1 *a–c*, p. 51.
Refigured as **Hexacrinus quintangulus**, G. F. Whidborne, Mon. Pal. Soc. 1895, pl. xxiii., figs. 6, 6 *a*, *b*, p. 198.
Middle Devonian. [7095] Newton Bushel.

Hexacrinus perarmatus, Whidborne. **T.**
G. F. Whidborne, Mon. Pal. Soc., 1895, pl. xxii., f. 10, p. 194.
Middle Devonian. [6879] Newton Bushel.

Hexacrinus quintangulus. *Vide* **Hexacrinus ? pentangularis.**

Hexacrinus Vicarii, Whidborne. **T.**
G. F. Whidborne, Mon. Pal. Soc., 1895, pl. xxiii., f. 4, p. 197. (See also *Platycrinus pentangularis ?*
Middle Devonian. [7093] Newton Bushel.

Lepidesthes ? devonicans (Whidborne). **T.**
G. F. Whidborne, Mon. Pal. Soc., 1898, pl. xxiv., figs. 1, 2 ; pl. xxv., f. 3 *a—f*. p. 200.
Upper Devonian (Pilton Beds). [7160, 7161] East of Barnstaple.

Ophiurella ? gregaria (Whidborne). **T.**
G. F Whidborne, Mon. Pal. Soc., 1898, pl. xxviii., f. 3, p. 210.
Upper Devonian (Pilton Beds). [7162] Braunton Down, N. Devon.

Palæaster longimanus, Whidborne. **T.**
G. F. Whidborne, Mon. Pal. Soc., 1898, pl. xxvi., figs. 1, 1*a*, 2, 3, 3*a*, *b*, p. 204.
Upper Devonian (Pilton Beds). [7162-7164]
Park near Braunton, and Baggy Point, North Devon.

Platycrinus interscapularis, Phillips. **T.**
J. Phillips, Pal. Foss., pl. xiv., f. 39, *a—d*, p. 28. Refigured as **Hexacrinus melo**, Austin, "Rec. and Foss. Crinoidea," 1843, pl. vi., f. 1 *a—e*, p. 48 ; and as **Hexacrinus interscapularis**, G. F. Whidborne, Mon. Pal. Soc., 1895, pl. xxi., f. 1, 1 *a—d*, p. 190.
Middle Devonian. [7088] Newton Bushel.

Platycrinus pentangularis ? Phillips. **[Doubtful] T.**
J. Phillips, Pal. Foss., pl. lx., f. 29**, p. 135. Refigured as **Hexacrinus Vicarii**, G. F. Whidborne, Mon. Pal. Soc., 1895, pl. xxiii., f. 5, p. 197.
Middle Devonian. [7092] Newton Bushel.

Platycrinus tuberculatus ?, Phillips.
J. Phillips, Pal. Foss., pl. lx., f. 39,* p. 134. Refigured as **Hexacrinus macrotatus**, T. Austin, "Rec. and Foss Crinoidea," 1843, pl. vi., f. 3 *b*, p. 50 ; Whidborne, Mon. Pal. Soc., 1895, pl. xxii., f. 8, p. 192.
Middle Devonian. [7094] Newton Bushel.

Poteriocrinus sp.
G. F. Whidborne, Mon. Pal. Soc., 1898, pl. xxxv., f. 4, p. 228.
Upper Devonian (Marwood Beds). [7155] Braunton Down, N. Devon.

Poteriocrinus sp.
G. F. Whidborne, Mon. Pal. Soc., 1898, pl. xxxvi., figs. 9, 9 *a*, p. 228
Upper Devonian (Marwood Beds). [7154] Braunton Down, N. Devon.

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Protaster granifer (Whidborne). T.
G. F. Whidborne, Mon. Pal. Soc., 1898, pl. xxvi., figs. 5, 6, p. 207.
Upper Devonian (Pilton Beds). [7165, 7166] North Devon.

Protaster ? (**Drepanaster**) **scabrosus**, Whidborne var. T.
G. F. Whidborne, Mon. Pal. Soc., 1898, pl. xxviii., figs. 1, 2, p. 208.
Upper Devonian. [7167, 7168] Croyde, N. Devon.
G. F. Whidborne, Mon. Pal. Soc., 1898, pl. xxix., figs. 2, 2 *a*, p. 208.
Upper Devonian (Pilton Beds). [7169] Braunton Down.

Protocidaris acuaria (Whidborne). T.
G. F. Whidborne, Mon. Pal. Soc., 1898, pl. xxv., figs. 1, 2, p. 203.
Upper Devonian (Pilton Beds). [7158, 7159] East of Barnstaple.

Rhodocrinus (**Acanthocrinus**) **sp.**
G. F. Whidborne, Mon. Pal. Soc., 1895, pl. xxiv., figs. 6, 6 *a*, p. 204.
Middle Devonian. [7096] Newton Bushel.

Rhodocrinus ?
G. F. Whidborne, Mon. Pal. Soc., 1898, pl. xxxi., f. 3 *a*–*d*, p. 217.
Upper Devonian (Marwood Beds). [7142, 7143] North Devon.

Scaphiocrinus ? inordinatus ? Whidborne.
G. F. Whidborne, Mon. Pal. Soc., 1898, pl. xxxiv., f. 7, p. 230.
Upper Devonian (Marwood Beds). [7151] Braunton, North Devon.

Scaphiocrinus ? plumifer, Whidborne. T.
G. F. Whidborne, Mon. Pal. Soc., 1898, pl. xxxvi., figs. 1, 1 *a*, p. 228.
Upper Devonian (Marwood Beds). [7153] Braunton, North Devon.

Scaphiocrinus sp.
G. F. Whidborne, Mon. Pal. Soc., 1898, pl. xxxiv., figs. 8, 8 *a*, p. 231.
Upper Devonian (Marwood Beds). [7152] Braunton, North Devon.

Sphærocrinus geometricus, Goldfuss.
G. F. Whidborne, Mon. Pal. Soc., 1895, pl. xxiv., f. 8, p. 211.
Middle Devonian. [6878] Newton Bushel.

Taxocrinus macrodactylus Phillips).
G. F. Whidborne, Mon. Pal. Soc., 1898, pl. xxxiii., figs. 3, 3 *a*, 4, 4 *a*, p. 215.
(See also *Cyathocrinus ?*)
Upper Devonian (Marwood Beds). [7149, 7150] North Devon.

Crustacea.

Brontes flabellifer, Goldfuss.
J. Phillips, Pal. Foss., pl. lvii., f. 254 *a*, p. 131.
Middle Devonian. [6985] Newton Bushel.

Calymene Latreillii, Steininger.
J. Phillips, Pal. Foss., pl. lvi., f. 249 *a*, *b*, p. 129.
Upper Devonian. [7054, 7055] New Road Qy., Pilton, Barnstaple.

Dechenella setosa (Whidborne). T.
G. F. Whidborne, Mon. Pal. Soc., 1899, pl. ii., figs. 16, 16 *a*, p. 27.
Middle Devonian. [6987] Newton Bushel

Homalonotus Herschelii ?, Murchison.
J. Phillips, Pal. Foss., pl. lvii., f. 253 *a*–*e*, p. 130.
Lower Devonian. [6872, 6873, 6874] Meadfoot Sands, Torquay.

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Phacops cryptophthalmus, Emmerich.
J. W. Salter, Mon. Pal. Soc., 1864, pl. i., f. 8, p. 17. Refigured as **Phacops latifrons** (Bronn): G. F. Whidborne, Mon. Pal. Soc., 1889, pl. i. figs. 8, 8*a*, p. 7.
Middle Devonian. [6986] Newton Bushel, Devon.

Phacops granulatus (Muenster). **[Doubtful.]**
J. W. Salter, Mon. Pal. Soc., 1864, pl. i., figs. 2, 3, 4, p. 18.
Upper Devonian. [7059, 7060] South Petherwin.

Phacops latifrons (Bronn).
J. W. Salter, Mon. Pal. Soc., 1864, pl. i., f. 9, p. 18.
Upper Devonian (Marwood Beds). [7057] North Devon.
J. W. Salter, Mon. Pal. Soc., 1864, pl. i., f. 10, p. 18.
Upper Devonian. [7053] Croyde.
J. W. Salter, Mon. Pal. Soc., 1864, pl. i., f. 14, p. 18; G. F. Whidborne, Mon. Pal. Soc., 1896, pl. i., f. 10, p. 10.
Upper Devonian. [7056] Baggy Point, North Devon.
G. F. Whidborne, Mon. Pal. Soc., 1896, pl. ii., f. 3, p. 11.
Upper Devonian. [7058] Brushford, North Devon.
(See also *P. cryptophthalmus.*)

Bryozoa.

Fenestella antiqua ?, Lonsdale.
J. Phillips, Pal. Foss., pl. xii., f. 35 *a*, p. 24.
Lower Devonian. [6876] West Lee, near Lynton, North Devon.

Fenestella arthritica, var. γ, Phillips. **T.**
J. Phillips, Pal. Foss., pl. xii., f. 36, p. 25.
Middle Devonian. [7108] Hope, Torquay.

Gorgonia ripisteria, Goldfuss.
J. Phillips, Pal. Foss., pl. xi., f. 30 *a*, *b*, p. 20.
Lower Devonian. [6877] Mudstone Bay, South Devon.

Hemitrypa oculata, Phillips. **T.**
J. Phillips, Pal. Foss., pl. xiii., f. 38 *a*, p. 27.
Middle Devonian. [7109] Hope, Torquay.

Millepora similis, Phillips. **T.**
J. Phillips, Pal. Foss., pl. xi., f. 32, p. 21.
Middle Devonian. [7110] Hope, Torquay.

Brachiopoda.

Athyris (Cleiothyris) Roissyii, Léveillé.
G. F. Whidborne, Mon. Pal. Soc., 1897, pl. xviii., figs. 1, 2, 2 *a*, p. 148.
(See also ? *Terebratula elongata.*)
Upper Devonian. [6994, 6995] Croyde, Devon.

Athyris phalæna. *Vide* **Spirifera.**

Atrypa desquamata (J. de C. Sowerby).
J. Phillips, Pal. Foss., pl. xxxiii., f. 146 *a*, p. 82.
Middle Devonian. [6911] Newton Bushel.

Atrypa flabellata, Goldf. MS.
T. Davidson, Mon. Pal. Soc., 1865, pl. xi., figs. 10, 10 *a*, 12 *a*, *b*, p. 59.
Middle Devonian. [6912] Wolborough, Newton.

Atrypa lens. *Vide* **Orthis.**

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Atrypa reticularis (Linnæus), var. **aspera**, Schlotheim.
T. Davidson, Mon. Pal. Soc., 1865, pl. x., figs. 5, 5 *a*, p. 57.
Middle Devonian. [6918] Newton Bushel.

[**Atrypa**.]
J. Phillips, Pal. Foss. pl. lx., f. 148,* p. 231. Refigured as **Pentamerus brevirostris**, Phillips: T. Davidson, Mon. Pal. Soc., 1865, pl. xv. f. 8, p. 72.
Middle Devonian. [6885] Wolborough, Newton Bushel.

Chonetes margaritacea, Whidborne. **T.**
G. F. Whidborne, Mon. Pal. Soc., 1898, pl. xxii., figs. 5, 5 *a*, 6, p. 179.
Upper Devonian. [6999] Braunton.

Cyrtina heteroclita. *Vide* **Spirifera**.

Davidsonia Verneuilii, Bouchard.
T. Davidson, Mon. Pal. Soc., 1865, pl. xi., figs. 14, 14 *a*, p. 74.
Middle Devonian. [6906] Orchard Quarry, Dartington.
T. Davidson, Mon. Pal. Soc., 1865, pl. xv., f. 18, p. 74.
Middle Devonian. [6905] Newton Bushel.

Discina nitida (Phillips).
T. Davidson, Mon. Pal. Soc., 1865, pl. xx., f. 10, p. 104.
Upper Devonian (Marwood Beds). [6989] West Angle Bay (S. side).
G. F. Whidborne, Mon. Pal. Soc., 1898, pl. xxii., f. 12, p. 183.
Upper Devonian. [6988] Barnstaple.

Leptæna analoga (Phillips).
J. Phillips, Pal. Foss., pl. xxiv., f. 93 *a*, p. 56.
Upper Devonian. [6993] Croyde Bay, Devon.

Leptæna laxispina (Phillips).
J. Phillips, Pal. Foss., pl. xxv., f. 99, p. 59. Refigured as **Strophalosia productoides**, Murchison: Davidson, Mon. Pal. Soc., 1865, pl. xix., f. 15, p. 97.
Upper Devonian. [7001] Petherwin, Cornwall.

Leptæna membranacea, Phillips. **T.**
J. Phillips, Pal. Foss., pl. xxv. f. 101 *a*, *s*, p. 60.
Upper Devonian (Pilton Group). [7002] Pilton, N. Devon.

Leptæna nodulosa, Phillips. **T.**
J. Phillips, Pal. Foss., pl. xxiv., f. 94 *a*, *b*, p. 56.
Middle Devonian. [6907, 6908] Hope, Torquay.

Orthis hipparionyx, Vanux. and Hall.
T. Davidson, Mon. Pal. Soc., 1865, pl. xvii., f. 9, p. 90.
Lower Devonian. [6865] Looe, Cornwall.

Orthis interlineata, J. de C. Sowerby.
T. Davidson, Mon. Pal. Soc., 1865, pl. xvii., f. 18, p. 91.
Upper Devonian. [6990] Landlake, Cornwall.
T. Davidson, Mon. Pal. Soc., 1865, pl. xvii., figs. 20, 22, p. 91.
Upper Devonian. [6991, 6992] Petherwin, Cornwall.

Orthis interstrialis, Phillips. **T.**
J. Phillips, Pal. Foss., pl. xxv., f. 103 *d*, p. 61.
Middle Devonian. [6909] Barton, South Devon.

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Orthis lens, Phillips.
J. Phillips, Pal. Foss. xxvi., f. 100 *a*, *b*, p. 65. Refigured as **Atrypa lens**, T. Davidson, Mon. Pal. Soc., 1865, pl. x, figs. 1, 1 *a–d*, p. 51.
Middle Devonian. [6914] Hope, Torquay.

Orthis longisulcata, Phillips. **T.**
J. Phillips, Pal. Foss., pl. xxvi., f. 105 *a*, p. 62.
Lower Devonian. [6864] Watersmeet, N. Devon.

Pentamerus brevirostris (Phillips).
T. Davidson, Mon. Pal. Soc., 1865, pl. xv., figs. 1, 1 *a*, *b*, p. 72. (See also *Terebratula cassidea*, *Strigocephalus*, and [*Atrypa*].)
Middle Devonian. [6889] Wolborough, Newton.

Productus prælongus, J. de C. Sowerby.
T. Davidson, Mon. Pal. Soc., 1865, pl. xix., f. 24, p. 102.
Upper Devonian (Pilton Beds). [6998] Croyde Bay, N. Devon.

Retzia ferita. *Vide* **Terebratula.**

Rhynchonella acuminata (Martin).
T. Davidson, Mon. Pal. Soc., 1865, pl. xiii., figs. 1, 1 *a*, *b*, p. 60.
Middle Devonian. [6890] Newton Bushel.

Rhynchonella angularis. *Vide* **Terebratula.**

Rhynchonella bifera (Phillips).
T. Davidson, Mon. Pal. Soc., 1865, pl. xii., f. 11, p. 64. (See also *Terebratula*.)
Middle Devonian. [6893] Hope, Torquay.

Rhynchonella laticosta (Phillips).
T. Davidson, Mon. Pal. Soc., 1865, pl. xiv., f. 2, p. 61. (See also *Terebratula*).
Upper Devonian (Marwood Beds). [7010] Sloly, Barnstaple.

Rhynchonella neapolitana, Whidborne. **T.**
G. F. Whidborne, Mon. Pal. Soc., 1893, pl. xv., figs. 4, 4 *a*, *b*, p. 129.
Middle Devonian. [6894] Newton.

Rhynchonella ? protracta (J. de C. Sowerby).
T. Davidson, Mon. Pal. Soc., 1865, pl. xiv., figs. 29, 29 *a*, p. 69.
Middle Devonian. [6921] Hope, Torquay.
(See also *Terebratula proboscidalis*.)

Rhynchonella reniformis. *Vide* **Terebratula subdentata.**

Rhynchonella (Camarotœchia) togata, Whidborne.
G. F. Whidborne, Mon. Pal. Soc., 1897, pl. xix., f. 15, p. 163.
Upper Devonian (Marwood Beds). [7013] North Devon.
G. F. Whidborne, Mon. Pal. Soc., 1897, pl. xix., f. 16, p. 163.
Upper Devonian. [7011] Marwood.
G. F. Whidborne, Mon. Pal. Soc., 1897, pl. xix., f. 18, p. 163.
Upper Devonian (Marwood Beds). [7012] Barnstaple.

Rhynchonella triloba (J. de C. Sowerby).
T. Davidson, Mon. Pal. Soc., 1865, pl. xii., figs. 4, 6, p. 64.
Middle Devonian. [6895, 6896] Newton Bushel.

Spirifera aperturata, Schlotheim ? **[Doubtful]**
J. Phillips, Pal. Foss., pl. xxx., f. 133, p. 77. Refigured as **Spirifera canalifera** (Valenciennes) : T. Davidson, Mon. Pal. Soc., 1864, pl. vi., f. 9, p. 26.
Lower Devonian. [6860] Lynton, N. Devon.

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Spirifera canalifera. *Vide* **S. aperturata.**

Spirifera costata, J. de C. Sowerby.
J. Phillips, Pal. Foss., pl. xxx., f. 134 *a*, p. 77. Refigured as **Spirifera speciosa?**, var. **paradoxa**, Schlotheim: Davidson, Mon. Pal. Soc., 1864, pl. viii., f. 11, p. 29.
Middle Devonian. [6922] Hope, Torquay.

Spirifera disjuncta, J. de C. Sowerby.
T. Davidson, Mon. Pal. Soc., 1864, pl. v., f. 6, p. 23. (See also *S. protensa.*)
Middle Devonian. [6917] Wolborough, Newton.

Spirifera disjuncta, var. **barumensis** (Sow. MS.), Salter.
T. Davidson, Mon. Pal. Soc., 1864, pl. vi., f. 2, p. 23.
Upper Devonian (Pilton Beds). [7004] Croyde Bay, N, Devon.

Spirifera heteroclita, Defrance.
J. Phillips, Pal. Foss., pl. xxix., f. 125 *a*, *d*, p. 72. Refigured as **Cyrtina heteroclita**: T. Davidson, Mon. Pal. Soc., 1864, pl. ix., f. 6, p. 48.
Middle Devonian. [6919] Newton Bushel.

Spirifera hirundo, Phillips. T.
J. Phillips, Pal. Foss., pl. xxviii., f. 122 *a*, *b*, *c*, p. 71. Refigured as **Athyris. phalæna** (Phil.): T. Davidson, Mon. Pal. Soc., 1864, pl. iii., figs. 21, 21 *a*, *b*, p. 18.
Lower Devonian. [6869] Hope, Torquay.

Spirifera ostiolata, Schlotheim.
J. Phillips, Pal. Foss., pl. xxx., f. 132 *a*, *c*, p. 76.
Lower Devonian. [6861] Valley of Rocks, Lynton, N. Devon.

Spirifera phalæna, Phillips. T.
J. Phillips, Pal. Foss., pl. xxviii., f. 123, p. 71. Refigured as **Athyris phalæna**: T. Davidson, Mon. Pal. Soc., 1864, pl. iii., f. 19, p. 18.
Lower Devonian. [6866] Hope, Torquay.

Spirifera obliterata, Phillips. T.
J. Phillips, Pal. Foss., pl. xxxi., f. 135, p. 78; G. F. Whidborne, Mon. Pal. Soc., 1897, pl. xix., f. 1, p. 156.
Upper Devonian (Pilton Beds). [6997] Brushford, North Devon.

Spirifera protensa, Phillips. T.
J. Phillips, Pal. Foss., pl. xxviii., f. 118 *a*, *b*, p. 69. Refigured as **Spirifer disjuncta**, J. de C. Sowerby: T. Davidson, Mon. Pal. Soc., 1864, pl. v., f. 12, p. 23.
Upper Devonian. [7000] Petherwin, Cornwall.

Spirifera simplex, Phillips. T.
J. Phillips, Pal. Foss., pl. lx., f. 124 *a* (two figures), p. 71; T. Davidson, Mon. Pal. Soc., 1864, pl. vi., figs. 19, 20, p. 46.
Middle Devonian. [6915, 6916] Wolborough, Newton.

Spirifera speciosa (Schlotheim).
T. Davidson, Mon. Pal. Soc., 1864, pl. viii., f. 7, p. 29.
Middle Devonian. [6923] Hope, Torquay.

Spirifera speciosa, var. **paradoxa**, Schlotheim.
T. Davidson, Mon. Pal. Soc., 1864, pl. viii., f. 13, p. 29. (See also *S. costata.*)
Lower Devonian. [6859] Fowey, Cornwall.

Spirifera undifera, Roemer.
T. Davidson, Mon. Pal. Soc., 1864, pl. vii., figs. 4, 4 *a*, *b*, p. 36.
Middle Devonian. [6924] Newton Bushel.

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Spirifera unguiculus (J. de C. Sowerby).
J. Phillips, Pal. Foss., pl. xxviii., f. 119 *b*, *c*, p. 69.
Upper Devonian. [7003] Petherwin, Cornwall.

Spirifera.
T. Davidson, Mon. Pal. Soc., 1864, pl. viii., f. 12, p. 33.
Middle Devonian (Shales). [6925] West Ogwell, Newton Bushel.

Strigocephalus brevirostris, Phillips. T.
J. Phillips, Pal. Foss., pl. xxxii., f. 143 *b*, p. 80. Refigured as **Pentamerus brevirostris**, T. Davidson, Mon. Pal. Soc., 1865, pl. xv., figs. 11, 11 *a*, p. 72.
Middle Devonian. [6886] Wolborough, Newton Bushel.

Strigocephalus giganteus (J. de C. Sowerby).
J. Phillips, Pal. Foss., pl. xxxii., f. 142 *b*, p. 80.
Middle Devonian. [6899] Bradley, Newton Bushel.

Stringocephalus Burtini, Defrance.
T. Davidson, Mon. Pal. Soc., 1864, pl. 1, f. 21, p. 11.
Middle Devonian. [6898] Chircombe Bridge, Devon.

Strophalosia productoides, Murchison.
T. Davidson, Mon. Pal. Soc., 1865, pl. xix., figs. 17, 17 *a*, p. 97.
Middle Devonian. [6910] East Ogwell, Newton.
T. Davidson, Mon. Pal. Soc., 1865, pl. xix., f. 20, p. 97.
Upper Devonian. [7002] Petherwin.
(See also *Leptæna laxispina*.)

Terebratula angularis, Phillips. T.
J. Phillips, Pal. Foss., pl. xxxv., f. 162 *b*, p. 89. Refigured as **Rhynchonella angularis**: T. Davidson, Mon. Pal. Soc., 1865, pl. xiv., f. 12 *a*, *b*, p. 68.
Middle Devonian. [6891] Wolborough, Newton.

Terebratula bifera, Phillips. T.
J. Phillips, Pal. Foss., pl. xxxiv., f. 151 *a*, *b*, p. 84. Refigured as **Rhynchonella bifera**: Davidson, Mon. Pal. Soc., 1865, pl. xii., f. 10, p. 64.
Middle Devonian. [6892] Hope, Torquay.

Terebratula (Atrypa) cassidea, Dalman.
J. Phillips, Pal. Foss., pl. xxxiv., f. 148 *a*, *b*, *c*, p. 83. Refigured as **Pentamerus brevirostris** (Phillips): T. Davidson, Mon. Pal. Soc., 1865, pl. xv., figs. 9, 9 *a*, *b*, 10, 10 *a*, *b*, p. 72.
Middle Devonian. [6887] Newton Bushel.

? Terebratula elongata (Schlotheim).
T. Davidson, Mon. Pal. Soc., 1864, pl. 1, f. 9, p. 8. Refigured as **Athyris, (Cleiothyris) Royssii**, Léveillé: G. F. Whidborne, Mon. Pal. Soc. 1897, pl. xvii., f. 13, p. 148.
Upper Devonian (Marwood Beds). [6996] East Hill, Braunton.

Terebratula ferita, v. Buch.
J. Phillips, Pal. Foss., pl. xxxv., f. 163 *a*, *b*, *c*, p. 89. Refigured as **Retzia ferita**: T. Davidson, Mon. Pal. Soc., 1864, pl. iv., f. 10, p. 21.
Middle Devonian. [6920] Newton Bushel.

Terebratula laticosta, Phillips. T.
J. Phillips, Pal. Foss., pl. xxxiv., f. 153 *a*, *b*, p. 85. Refigured as **Rhynchonella laticosta**: T. Davidson, Mon. Pal. Soc., 1865, pl. xiv., f. 1, p. 61.
Upper Devonian (Marwood Beds). [7005, 7006] Baggy Point, N. Devon,

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Terebratula proboscidalis, Phillips. T.
J. Phillips, Pal. Foss., f. 149, p. 84. Refigured as **Rhynchonella ? protracta**: T. Davidson, Mon. Pal. Soc., 1865, pl. xiv., f. 30, p. 69.
Middle Devonian. [6921] Hope, Torquay.

Terebratula subdentata, J. de C. Sowerby.
J. Phillips, Pal. Foss., pl. xxxv., f. 164, p. 90. Refigured as **Rhynchonella reniformis** (J. de C. Sowerby): T. Davidson, Mon. Pal. Soc., 1865, pl. xiii., f. 7, p. 62
Upper Devonian. [7007] Petherwin, Cornwall.

LAMELLIBRANCHIATA.

Actinopteria hirundella (Whidborne). T.
G. F. Whidborne, Mon. Pal. Soc., 1892, pl. vi., figs. 5, 5 *a*, p. 61.
Middle Devonian. [6902] Newton Bushel.

Actinopteria texturata (Phillips).
G. F. Whidborne, Mon. Pal. Soc., 1892, pl. ix., f. 6, p. 74.
Middle Devonian. [6882] Newton Bushel.

Avicula damnoniensis, J. de C. Sowerby.
J. Phillips, Pal. Foss., pl. xxiii., f. 91 *c*, p. 51. (See also *Ptychopteria*.)
Upper Devonian. [7020] Marwood, N. Devon.

Avicula subradiata, J. de C. Sowerby.
J. Phillips, Pal. Foss., pl. xxi., f. 86, p. 50.
Upper Devonian. [7017] Petherwin, Cornwall.

Aviculopecten transversus. *Vide* **Pecten**.

Conocardium clathratum. *Vide* **Pleurorhynchus aliformis**.

Crenipecten ? Oceani. *Vide* **Pecten plicatus**.

Ctenodonta (Palæoneilo) lirata (Phillips).
G. F. Whidborne, Mon. Pal. Soc., 1896, pl. xii., f. 12, p. 100. (See also *Nucula*, *Sanguinolaria*, and *Pullastra*.)
Upper Devonian (above Marwood Beds). [7022] Baggy, N. Devon.

Ctenodonta (Koenenia) cf. obsoleta (Goldfuss).
G. F. Whidborne, Mon. Pal. Soc., 1896, pl. xii., f. 10, p. 106.
Upper Devonian (Marwood Beds). [7025] Baggy Point, North Devon.

Ctenodonta ? tensa, Whidborne. T.
G. F. Whidborne, Mon. Pal. Soc., 1896, pl. xii., figs. 9, 9 *a*, p. 104.
Upper Devonian (Marwood Beds). [7026] Barnstaple.

Cucullæa amygdalina, Phillips. T.
J. Phillips, Pal. Foss., pl. xviii., f. 66 *a—d*, p. 40.
Upper Devonian. [7034] Marwood, North Devon.

Cucullæa angusta, J. de C. Sowerby.
J. Phillips, Pal. Foss., pl. xix., f. 68 *a—c*, p. 41.
Upper Devonian. [7035] Marwood, N. Devon.

Cucullæa depressa, Phillips. T.
J. Phillips, Pal. Foss., pl. xix., f. 71 *a—c*, p. 42. Fig. 71 *a*, *b*, refigured G. F. Whidborne, Mon. Pal. Soc., pl. xii., figs. 3, 3 *a*, p. 111.
Upper Devonian. [7027, 7028] Marwood.
G. F. Whidborne, Mon. Pal. Soc. 1896, pl. xii., f. 2, p. 111.
Upper Devonian. [7029] Marwood.

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Cucullæa Hardingii, J. de C. Sowerby.
J. Phillips, Pal. Foss., pl. xviii., f. 67 *a*, *b* ; pl. xix, f. 67 *a*, *b*, p. 40.
Upper Devonian. [7030–7033] Marwood, North Devon.

Cucullæa trapezium, J. de C. Sowerby.
J. Phillips, Pal. Foss., pl. xix., f. 70, p. 41.
Upper Devonian. [7037] Marwood, North Devon.

Cucullæa unilateralis, J. de C. Sowerby.
J. Phillips, Pal. Foss., pl. xix., f. 69 *a*—*c*, p. 41. Fig. 69 *c* refigured G. F. Whidborne, Mon. Pal. Soc., 1896, pl. xiii., figs. 10, p. 109.
Upper Devonian. [7036] Marwood, North Devon.

Cypricardia deltoidea, Phillips. T
J. Phillips, Pal. Foss., pl. xvii., f. 59, p. 37. Refigured as **Myophoria deltoidea** : G. F. Whidborne, Mon. Pal. Soc., 1896, pl. x., figs. 7, 7 *a*, p. 93.
Upper Devonian. [7039] South Petherwin, Cornwall.

Cypricardinia reticulata (Phillips).
G. F. Whidborne, Mon. Pal. Soc., 1892, pl. i., f. 12, p. 11.
Middle Devonian. [6932] Newton Bushel.

Cypricardia semisulcata (J. de C. Sowerby). **[Doubtful]**
J. Phillips, Pal. Foss., pl. xvii., f. 57 *b*, *c*, p. 36.
Upper Devonian. [7051] Landlake, Cornwall.

Digoniomya elegans, Whidborne. T.
G. F. Whidborne, Mon. Pal. Soc., 1896, pl. xiii., f. 13, p. 117.
Upper Devonian. [7052] Croyde, North Devon.

Goniophora obliqua (Whidborne). T.
G. F. Whidborne, Mon. Pal. Soc., 1892, pl. iii., f. 1, 1 *a*, *b*, p. 16.
Middle Devonian. [6933] Newton Bushel.

Hoplomytilus crassus, Sandberger.
G. F. Whidborne, Mon. Pal. Soc., 1892, pl. iv., figs. 2, 2 *a*, p. 44.
Middle Devonian. [6904] Newton Bushel.

Leptodesma citimum, Whidborne. T.
G. F. Whidborne, Mon. Pal. Soc., 1897, pl. xiii., figs. 7, 7 *a*, p. 120.
Upper Devonian. [7014] Marwood, N. Devon.

Leptodesma cultellatum, Whidborne. T.
G. F. Whidborne, Mon. Pal. Soc., 1896, pl. xiv., figs. 2, 2 *a*, p. 121.
Upper Devonian (Marwood Beds). [7016] Braunton, N. Devon.

Leptodomus constricta, McCoy.
G. F. Whidborne, Mon. Pal. Soc., 1896, pl. viii., f. 8, p. 75.
Upper Devonian. [7050] Marwood, North Devon.

Mecynodon carinatus (Goldfuss).
G. F. Whidborne, Mon. Pal. Soc., 1892, pl. ii., figs. 15, 15 *a*, *b*, p. 34.
Middle Devonian. [6926] Newton Bushel ?

Modiola scalaris, Phillips. T.
J. Phillips, Pal. Foss., pl. lx., f. 62*, p. 137.
Middle Devonian. [6931] Berry Pomeroy, Torquay.

Modiolopsis lepida (Whidborne). T.
G. F. Whidborne, Mon. Pal. Soc., 1892, pl. i., f. 5, p. 41.
Middle Devonian. [6930] Newton Bushel.

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Modiolopsis sp.
G. F. Whidborne, Mon. Pal. Soc., 1896, pl. xii., f. 7, p. 114.
Upper Devonian (Marwood Beds). [7024] South Cave, Baggy Point.

Myalina damnoniensis. *Vide* **Mytilus.**

Myalina stulta (Whidborne). T.
G. F. Whidborne, Mon. Pal. Soc., 1892, pl. iii., f. 8, p. 48.
Middle Devonian. [6929] Newton Bushel.

Myophoria deltoidea (Phillips).
G. F. Whidborne, Mon. Pal. Soc., 1896, pl. x., figs. 5, 5*a*, *b*, p. 93.
Upper Devonian. [7038] Marwood.
G. F. Whidborne, Mon. Pal. Soc., 1896, pl. x., f. 8, p. 93.
Upper Devonian (Marwood Beds). [7040] Sherwell, Barnstaple.
(See also *Cypricardia.*)

Myophoria inflata (F. A. Roemer).
G. F. Whidborne, Mon. Pal. Soc., 1896, pl. x., figs. 3, 3 *a*, 4, 4 *a*, p. 92.
Old Red Sandstone (Coomhola Grit) [7041, 7042] County Cork.

Myophoria trigona (F. A. Roemer).
G. F. Whidborne, Mon. Pal. Soc., 1896, pl. x., f. 9, p. 96.
Upper Devonian (Marwood Beds). [7043] Croyde Bay.

Mytilarca ? modioloides, Whidborne. T.
G. F. Whidborne, Mon. Pal. Soc., 1896, pl. xiii., f. 8, p. 117.
Upper Devonian (Marwood Beds). [7023] Braunton, North Devon.

Mytilus ? damnoniensis, Phillips. T.
J. Phillips, Pal. Foss., 1841, pl. xviii., f. 61, p. 37. Refigured as **Myalina damnoniensis**: G. F. Whidborne, Mon. Pal. Soc., 1892, pl. iii., f. 6, p. 47.
Middle Devonian. [6928] Newton Bushel.

Nucula latissima, Phillip. [Doubtful.]
J. Phillips, Pal. Foss. pl. lviii., f, 65,* p. 137. Refigured as **Ctenodonta (Palæoneilo) lirata** (Phillips): G. F. Whidborne, Mon. Pal. Soc 1896, pl. xii., f. 12, p. 100.
Upper Devonian (above Marwood Beds).
[7022] Baggy, North Devon.

Nucula ovata, J. de C. Sowerby.
J. Phillips, Pal. Foss., pl. xviii., f. 65, p. 39.
Lower Devonian. [6868] Meadfoot Sands, Torquay.

Pecten granulosus, Phillips. T.
J. Phillips, Pal. Foss., pl. xxi., f. 75 *a*, *b*, *c*, p. 46.
Upper Devonian. [7008] Landlake, Cornwall.

Pecten plicatus, J. de C. Sowerby.
J. Phillips, Pal. Foss., pl. lx., f. 80*, p. 137. Refigured as **Crenipecten ? Oceani** (Goldfuss): G. F. Whidborne, Mon. Pal. Soc., 1892, pl. x. f. 6, p. 89.
Middle Devonian. [6903] Newton Bushel.

Pecten transversus, J. de C. Sowerby.
J. Phillips, Pal. Foss., pl. xxi., f. 77, *a*, *b*, p. 46. Refigured as **Aviculopecten transversus**: G. F. Whidborne, Mon. Pal. Soc., 1896, pl. xvi., f. 2, p. 127.
Upper Devonian (Pilton Beds). [7009] Brushford, N. Devon.

Pleurorhynchus aliformis, J. de C. Sowerby.
J. Phillips, Pal. Foss., pl. xvii., f. 51, p. 34. Refigured as **Conocardium clathratum**, d'Orbigny: G. F. Whidborne, Mon. Pal. Soc., pl. i., f. 20., p. 18.
Middle Devonian. [6927] Newton Bushel.

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Prothyris recta, Whidborne. **T.**
G. F. Whidborne, Mon. Pal. Soc., 1896, pl. ix., figs. 12, 13, 14, p. 86.
Upper Devonian. [6085*a*, *b*, *c*] South Cave, Baggy, N. Devon.

Prothyris scalprata, Whidborne. **T.**
G. F. Whidborne, Mon. Pal. Soc., 1896, pl. ix., f. 17, p. 88.
Upper Devonian. [7044] Barnstaple.

Pterinea bellula (Whidborne). **T.**
G. F. Whidborne, Mon. Pal. Soc., 1892, pl. iv., f. 11, p. 57.
Middle Devonian. [6901] Newton Bushel.

Pterinea ? spinosa, Phillips. **T.**
J. Phillips, Pal. Foss., pl. xxii., f. 81 *a*, *d*, p. 48.
Lower Devonian. [6867] Woodabay, N. Devon.

Pterinopecten ? Hallii, Whidborne. **T.**
G. F. Whidborne, Mon. Pal. Soc., 1896, pl. xv., f. 4, p. 134.
Upper Devonian. [7018] Petherwin, Cornwall.

Pterinopecten polytrichus (Phillips).
G. F. Whidborne, Mon. Pal. Soc., 1896, pl. xv., f. 1, p. 132.
Upper Devonian (Pilton Beds). [7019] Croyde Bay, N. Devon.

Ptychopteria damnoniensis (J. de C. Sowerby).
G. F. Whidborne, Mon. Pal. Soc., 1896, pl. xiv., figs. 9, 9*a*, p. 126.
Upper Devonian (Marwood Beds) [7446] West Angle Bay, Pembrokesh.
G. F. Whidborne, Mon. Pal. Soc., 1896, pl. xiv., figs. 11, 11 *a*, *b*, p. 126.
Upper Devonian. [7021] Marwood.
(See also *Avicula*.)

Pullastra antiqua, J. de C. Sowerby.
J. Phillips, Pal. Foss., pl. xvii., f. 55 *a*, *b*, p. 35. Refigured as **Ctenodonta (Palæoneilo) lirata** (Phillips): G. F. Whidborne, Mon. Pal. Soc., 1896, pl. xiii., f. 4, p. 100.
Upper Devonian (Pilton Beds). [7023] Barnstaple.

Pullastra ? complanata, J. de C. Sowerby. **[Doubtful]**
J. Phillips, Pal. Foss., pl. xvii., f. 56, p. 35. Refigured as **Sphenotus Hicksii, T,** G. F. Whidborne, Mon. Pal. Soc., 1896, pl. ix., f. 9, p. 83.
Upper Devonian (Marwood Beds). [7049] Barnstaple.

Rutotia elliptica (Whidborne). **T.**
G. F. Whidborne, Mon. Pal. Soc., 1892, pl. v., f. 3, p. 55.
Middle Devonian. [6900] Newton Bushel.

Sanguinolaria elliptica, Phillips. **T.**
J. Phillips, Pal. Foss., pl. xvii., f. 53 *a*--*d*, p. 34.
Upper Devonian (Pilton Beds). [7045, 7046] Combe, Ashburton.

Sanguinolaria lirata, Phillips. **T.**
J. Phillips, Pal. Foss., pl. lviii., f. 53* *a*, *b*, p. 136. Refigured as **Ctenodonta (Palæoneilo) lirata** : G. F. Whidborne, Mon. Pal. Soc., 1896, pl. xiii., f. 1, p. 100.
Upper Devonian (Pilton Beds). [7024] Pilton, N. Devon.

Sanguinolaria sulcata, Muenster. **[Doubtful]**
J. Phillips, Pal. Foss., pl. xvii., f. 52 *b*, p. 34.
Upper Devonian (Pilton Beds). [7048] Combe, Ashburton.

Sanguinolites mimus, Whidborne. **T.**
G. F. Whidborne, Mon. Pal. Soc., 1896, pl ix., f. 4, p 78.
Upper Devonian (Marwood Beds) [7047] Near Croyde.

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Scaldia ? longa, Whidborne. T.
G. F. Whidborne, Mon. Pal. Soc., 1896, pl. x., figs. 1, 1 *a*, 2, p. 89.
Upper Devonian (Marwood Beds) [7025] South Cave, Baggy Point.

Sphenotus Hicksii. *Vide* **Pullastra ? Complanata.** T.

GASTEROPODA.

Acroculia sigmoidalis, Phillips. T.
J. Phillips, Pal. Foss., pl. xxxvi., f. 170, p. 94.
Middle ? Devonian [6883] Hope, Torquay.

Acroculia vetusta, J. de C. Sowerby.
J. Phillips, Pal. Foss., pl. xxxvi., f. 169 *b*, p. 93. Refigured as **Capulus contortus** ? (F. A. Roemer): G. F. Whidborne, Mon. Pal. Soc., 1891, pl. xxii., figs, 6, 6 *a*, *b*, p. 218.
Middle Devonian. [6957] Newton Bushel.

Antitrochus arietinus, Whidborne. T.
G. F. Whidborne, Mon. Pal. Soc., 1891, pl. xxiii., figs., 11-13, p. 235.
Middle Devonian. [6964-6] Newton Bushel.

Bellerophon imperforatus, Whidborne. T.
G. F. Whidborne, Mon. Pal. Soc., 1892, pl. xxxi., figs. 11, 11 *a*, p. 329.
Middle Devonian. [6936] Newton Bushel.

Bellerophon labyrinthodes, Whidborne. T.
G. F. Whidborne, Mon. Pal. Soc., 1896, pl. viii., figs, 2, 2 *a*, *b*, p. 63.
Upper Devonian. [7061] Baggy Point, N. Devon.

Bellerophon lineatus, Goldfuss, MS.
G. F. Whidborne, Mon. Pal. Soc., 1892, pl. xxxi., figs. 6, 6 *a*, *b*, p. 321.
Middle Devonian. [6937] Newton Bushel.

Bellerophon subglobatus, M'Coy.
G. F. Whidborne, Mon. Pal. Soc., 1896, pl. viii., figs. 3, 3 *a*, p. 64.
Upper Devonian (Marwood Beds). [7062] North Devon.

Bellerophon Urii, Fleming.
J. Phillips, Pal. Foss., pl. xl., f. 199 *a–d*, p. 106. Refigured as **Euphemus barumensis**, , Whidborne, Mon. Pal. Soc., 1896, pl. vii., f. 2, p. 70.
Upper Devonian (Marwood Beds).
[7063] Baggy Point, N. Devon.

Capulus contortus ? (F. A. Roemer).
G. F. Whidborne, Mon. Pal. Soc., 1891, pl. xxii., figs. 5, 5 *a*, *b*, p. 218.
(See also *Acroculia vetusta*.)
Middle Devonian. [6956] Newton Bushel.

Capulus cordatus (Whidborne). T.
G. F. Whidborne, Mon. Pal. Soc., 1891, pl. xxi., figs. 1, 1 *a*, p. 212.
Middle Devonian. [6958] Newton Bushel.

Capulus galeritus, Whidborne. T.
G. F. Whidborne, Mon. Pal. Soc., 1891, pl. xxii., f. 3, 3 *a*, p. 217.
Middle Devonian. [6959] Newton Bushel.

Capulus puellaris, Whidborne. T.
G. F. Whidborne, Mon. Pal. Soc., 1891, pl. xx., f. 13, 13 *a*, p. 210.
Middle Devonian. [6960] Newton Bushel.

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Euomphalus annulatus, Phillips. **T.**
J. Phillips, Pal. Foss., pl. lx., f. 172*, p. 138. (*E. annulosus* on p. 231); G. F. Whidborne, Mon. Pal. Soc., 1891, pl. xxiv., figs. 6, 6 *a*, p. 250.
Middle Devonian. [6950] Newton Bushel.

Euomphalus circularis, Phillips. **T.**
J. Phillips, Pal. Foss., pl. xxxvi., f. 171, p. 94.
Middle Devonian. [6982] Newton Bushel.

Euomphalus germanus (Phillips).
G. F. Whidborne, Mon. Pal. Soc., 1892, pl. xxv., figs. 4, 4 *a*, p. 256. (See also *Nautilus germanus*.)
Middle Devonian. [6951] Newton Abbot.

Euomphalus Hecale, Hall.
G. F. Whidborne, Mon. Pal. Soc., 1891, pl. xxiv., figs. 7, 7*a*, p. 247.
Middle Devonian. [6953] Newton Bushel.

Euomphalus radiatus ? Goldfuss MS.
J. Phillips, Pal. Foss., pl. lx., f. 171*, p. 138. Refigured as **Euomphalus rota**, Sandberger: G. F. Whidborne, Mon. Pal. Soc., 1892, pl. xxv. f. 8, p. 258.
Middle Devonian. [6952] Newton Bushel.

Euomphalus rota. *Vide* **E. radiatus ?**

Euomphalus serpens, Phillips. **[Doubtful.]**
J. Phillips, Pal. Foss., pl. xxxvi., f. 172, p. 94.
Upper Devonian (Pilton Beds). [7069] Brushford, N. Devon.

Euphemus barumensis. *Vide* **Bellerophon Urii.**

Flemingia perversa (Whidborne). **T.**
G. F. Whidborne, Mon. Pal. Soc., 1892, pl. xxvii., figs. 4, 4 *a*, p. 267.
Middle Devonian. [6962] Newton Bushel.

Helminthochiton papilio (Whidborne). **T.**
G. F. Whidborne, Mon. Pal. Soc., 1892, pl. xxxi., f. 15, p. 334.
Middle Devonian [6935] Newton Bushel.

Holopella costata, Sandberger.
G. F. Whidborne, Mon. Pal. Soc., 1891, pl. xviii., figs. 15, 15 *a*, p. 229.
Middle Devonian. [6967] Newton Bushel.

Holopella tenuisulcata, Sandberger.
G. F. Whidborne, Mon. Pal. Soc., 1891, pl. xviii., f. 11, p. 225.
Middle Devonian. [6963] Newton Bushel.

Loxonema anglicum, d'Orbigny.
G. F. Whidborne, Mon. Pal. Soc., 1896, pl. v., f. 6, p. 43.
Upper Devonian (Marwood Beds). [7073] Braunton Down, N. Devon.

Loxonema ? præterita, Phillips. **T.**
J. Phillips, Pal. Foss., pl. xxxviii., f. 187 *c*, p. 100.
Middle Devonian. [6884] Hope, Torquay.
J. Phillips, Pal. Foss., pl. xxxviii., f. 187 *a*, *b*, p. 100. Refigured as **Loxonema reticulatum** (Phillips): G. F. Whidborne, Mon. Pal. Soc., 1891, pl. xviii., f. 2, p. 177.
Middle Devonian. [6977, 6978] Chudleigh, Devon.

Loxonema priscum (Muenster).
G. F. Whidborne, Mon. Pal. Soc., 1891, pl. xviii., f. 17, p. 181.
Middle Devonian. [6970] Newton Bushel.

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Loxonema reticulata, Phillips. T.
J. Phillips, Pal. Foss., pl. lx., f. 187*, p. 139; G. F. Whidborne, Mon. Pal. Soc., 1891, pl. xviii., figs. 3, 3 *a*, *b*, p. 177.
Middle Devonian. [6972] Newton Bushel.
G. F. Whidborne, Mon. Pal. Soc., 1891, pl. xviii., f. 1, p. 177.
Middle Devonian. [6971] Newton Bushel.
(See also *L. ? præterita.*)

Loxonema Roemeri, Kayser.
G. F. Whidborne, Mon. Pal. Soc., 1891, pl. xvii., figs. 18, 18 *a*, p. 172.
Middle Devonian. [6973] Newton Bushel.

Loxonema sinuosa (J. de C. Sowerby). [Doubtful.]
J. Phillips, Pal. Foss., pl. xxxviii., f. 182, p. 99.
Upper Devonian. [7074] South Petherwin, Cornwall.

Macrocheilus arculatus ? Phillips. T.
J. Phillips, Pal. Foss., pl. lx., f. 194,* p. 139. Refigured as **Macrochilina subcostata** (Schlotheim): G. F. Whidborne, Mon. Pal. Soc., 1891, pl. xvi., f. 3, p. 159.
Middle Devonian. [6979] Newton Bushel.

Macrocheilus elongatus, Phillips. T.
J. Phillips, Pal. Foss., pl. xxxix., f. 195, p. 104. Refigured as **Macrochilina subcostata** (Schlotheim): G. F. Whidborne, Mon. Pal. Soc., 1891, pl. xvi., f. 7, p. 159.
Middle Devonian. [6976] Newton Bushel.

Macrochilina elevata, Whidborne. T.
G. F. Whidborne, Mon. Pal. Soc., 1891, pl. xvii., figs. 12, 12 *a*, p. 170.
Middle Devonian. [6974] Newton Bushel.

Macrochilina imbricata (J. de C. Sowerby).
G. F. Whidborne, Mon. Pal. Soc., 1891, pl. xvii., f. 2, p. 164.
Middle Devonian. [6975] Newton Bushel.

Macrochilina subcostata. *Vide* **Macrocheilus arculatus ?** and **M. elongatus.**

Macrochilina ventricosa (Goldfuss).
G. F. Whidborne, Mon. Pal. Soc., 1891, pl. xvii., figs. 8, 8 *a*, 9, p. 167.
Middle Devonian. [6980, 6981] Newton Bushel.

Michelia sp.
G. F. Whidborne, Mon. Pal. Soc., 1891, pl. xviii., f. 6, p. 183.
Middle Devonian. [6984] Newton Bushel.

Murchisonia geminata, Phillips.
J. Phillips, Pal. Foss., pl. xxxix., f. 190, p. 102. Refigured as **Murchisonia turbinata** (Schlotheim): G. F. Whidborne, Mon. Pal. Soc., 1892, pl. xxx., f. 11, p. 306.
Middle Devonian. [6941] Newton Bushel.

Murchisonia spinosa (J. de C. Sowerby).
J. Phillips, Pal. Foss., pl. xxxix., f. 192 *b*, *c*, p. 102. Refigured as **Murchisonia turbinata** (Schlotheim): G. F. Whidborne, Mon. Pal. Soc., 1892, pl. xxix., figs. 13, 16, p. 306.
Middle Devonian. [6939, 6940] Newton Bushel.

Murchisonia trepomena. *Vide* **M. tricincta.**

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Murchisonia tricincta (Muenster).
J. Phillips, Pal. Foss., pl. lx., f. 190*, p. 139. Refigured as **Murchisonia trepomena, T,** Whidborne. Mon. Pal. Soc., 1892, pl. xxx., figs. 16, 16 *a*, p. 315.
Middle Devonian. [6938] Newton Bushel.

Murchisonia turbinata (Schlotheim).
G. F. Whidborne, Mon. Pal. Soc., 1892, pl. xxx., f. 8, p. 306. (See also *M. geminata* and *M. spinosa*.)
Middle Devonian. [6942] Newton Bushel.

Murchisonia, sp.
G. F. Whidborne, Mon. Pal. Soc., 1896, pl. vi., f. 15, p. 60.
Upper Devonian. [7065] Baggy Point, N. Devon.

Naticopsis Hallii, Whidborne. **T.**
G. F. Whidborne, Mon. Pal. Soc., 1896, pl. v., figs. 11, 12, p. 44.
Upper Devonian (Marwood Beds). [7070, 7071] North Devon.

Nautilus germanus, Phillips. **T.**
J. Phillips, Pal. Foss., pl. xlviii., f. 226 *a*, *b*, p. 118. Refigured as **Euomphalus germanus**: G. F. Whidborne, Mon. Pal. Soc., 1892, pl. xxv., figs. 4, 4*a*, p. 256.
Middle Devonian. [6951] Newton Bushel.

Phanerotinus mundus, Whidborne. **T.**
G. F. Whidborne, Mon. Pal. Soc., 1892, pl. xxv., f. 12, p. 261.
Middle Devonian. [6954] Newton Bushel.

Philoxene lævis, d'Archaic and de Verneuil.
G. F. Whidborne, Mon. Pal. Soc., 1891, pl. xxiii., figs. 18, 18 *a*, p. 239
Middle Devonian. [6955] Newton Bushel.

Platyostoma? deforme (J. de C. Sowerby.)
G. F. Whidborne, Mon. Pal. Soc., 1891, pl. xxiii., figs. 3—5, p. 200.
Middle Devonian. [6961, 6983, 7221] Newton Bushel.

Pleurotomaria antitorquata (Muenster.)
J. Phillips, Pal. Foss., pl. xxxvii., f. 176 *d*, p. 96.
Upper Devonian. [7072] South Petherwin, Cornwall.

Pleurotomaria aspera (J. de C. Sowerby).
J. Phillips, Pal. Foss., pl. xxxvii., f. 177,* p. 96. Refigured as **P. (Gyroma) aspera**: G. F. Whidborne, Mon. Pal. Soc., 1896, pl. vi., f. 12, p. 57.
Upper Devonian. [7067] South Petherwin.
G. F. Whidborne, Mon. Pal. Soc., 1896, pl. vi., figs. 10, 10 *a*, *b*, p. 57.
Upper Devonian (Marwood Beds). [7066] E. of Barnstaple.
G. F. Whidborne, Mon. Pal. Soc., 1896, pl. vi., f. 11, p. 57.
Upper Devonian. [7068] South Petherwin.

Pleurotomaria cancellata, Phillips. **T.**
J. Phillips, Pal. Foss., pl. xxxvii., f. 176 *a*, *b*, p. 96; G. F. Whidborne, Mon. Pal. Soc., 1892, pl. xxviii., f. 4. p. 291.
Middle Devonian. [6881] Newton Bushel.

Pleurotomaria Champernowni, Whidborne. **T.**
G. F. Whidborne, Mon. Pal. Soc., 1892, pl. xxvi., figs. 5, 5 *a*, p. 277.
Middle Devonian. [6943] Newton Bushel.

Pleurotomaria dissimulatrix, Whidborne. **T.**
G. F. Whidborne, Mon. Pal. Soc., 1892, pl. xxviii., f. 17, p. 300.
Middle Devonian. [6945] Newton Bushel

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Pleurotomaria Lonsdalii, d'Archaic and de Verneuil.
G. F. Whidborne, Mon. Pal. Soc., 1892, pl. xxvii., f. 12, p. 280.
Middle Devonian. [6946] Newton Bushe .

Pleurotomaria neapolitana, Whidborne. T.
G. F. Whidborne, Mon. Pal. Soc., 1892, pl. xxvii., f. 16, p. 286.
Middle Devonian. [6947] Newton Bushel

Pleurotomaria subclathrata, Sandberger.
G. F. Whidborne, Mon. Pal. Soc., 1892, pl. xxvii., f. 11, p. 278.
Middle Devonian. [6948] Newton Bushel.

Pleurotomaria subimbricata, Whidborne. T.
G. F. Whidborne, Mon. Pal. Soc., 1892, pl. xxviii., f. 8, p. 293.
Middle Devonian. [6949] Newton Bushel.

Porcellia bifida (Sandberger).
G. F. Whidborne, Mon. Pal. Soc., 1892, pl. xxxi., figs. 12, 12 *a*, *b*, p. 330.
Middle Devonian. [6944] Newton Bushel.

Scoliostoma texatum. *Vide* **Turbo.**

Tropidodiscus trilobatus (J. de C. Sow.?), var. **bisulcatus**, F. A. Roemer.
G. F. Whidborne, Mon. Pal. Soc., 1896, pl. viii., f. 6, 6 *a*, p. 68.
Upper Devonian (Marwood Beds). [7064] Baggy Point, N. Devon.

Turbo texatus (Muenster).
J. Phillips, Pal. Foss., pl. xxxvii., f. 175 *a*, *b*, p. 95. Refigured as **Scoliostoma texatum**: G. F. Whidborne, Mon. Pal. Soc., 1891, pl. xxiii., figs. 7, 8, p. 231.
Middle Devonian. [6968, 6969] Newton Bushel.

Cephalopoda.

Actinoceras? (Huronia) Crickii, Whidborne. T.
G. F. Whidborne, Mon. Pal. Soc., 1896, pl. iv., f. 9, p. 33.
Upper Devonian. [7075] Baggy, N. Devon.

Clymenia fasciata, Phillips. T.
J. Phillips, Pal. Foss., pl. liii., f. 242 *a–d*, p. 125.
Upper Devonian. [7172] South Petherwin.

Clymenia lævigata, Muenster.
J. Phillips, Pal. Foss., pl. lii., f. 239 *a–c*, p. 124.
Upper Devonian. [7173] South Petherwin.

Clymenia linearis, Muenster.
J. Phillips, Pal. Foss., pl. liii., f. 241 *a*, *b*, p. 125.
Upper Devonian. [7176] South Petherwin.

Clymenia plurisepta, Phillips. T.
J. Phillips, Pal. Foss., pl. liv., f. 244 *a–c*, p. 126.
Upper Devonian. [7174] South Petherwin.

Clymenia sagittalis, Phillips. T.
J. Phillips, Pal Foss., pl. liv., f. 243 *a–c*, p. 125.
Upper Devonian. [7175] South Petherwin.

Clymenia striata (Muenster).
J. Phillips, Pal. Foss., pl. liii., f. 240 *a*, *b*, p. 125.
Upper Devonian. [7082] South Petherwin

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Clymenia valida, Phillips. T.
J. Phillips, Pal. Foss., pl. liv., f. 245 *a*, *b*, p. 126.
Upper Devonian. [7177] South Petherwin.

Cyrtoceras armatum, Phillips. T.
J. Phillips, Pal. Foss., pl. xlviii., f. 225 *a*, *b*, p. 118. Refigured as **Gyroceras armatum**: G. F. Whidborne, Mon. Pal. Soc., 1890, pl. xii., figs. 1, 1 *a*, p. 99.
Middle Devonian. [7098] Newton Bushel.

Cyrtoceras? fimbriatum, Phillips.
G. F. Whidborne, Mon. Pal. Soc., 1890, pl. x., figs. 3, 3 *a*, p. 104.
Middle Devonian. [7104] Newton Bushel.

Cyrtoceras obliquatum, Phillips. T.
J. Phillips, Pal. Foss., pl. xlv., f. 218 *a*, *b*, *d*, *e*, p. 115. Refigured as **Trochoceras obliquatum**: G. F. Whidborne, Mon. Pal. Soc., 1890, pl. ix., figs. 5, 5 *a*, *b*, p. 86.
Middle Devonian. [7120] Newton Bushel.

Cyrtoceras ornatum? (Goldfuss MS.). Phillips.
J. Phillips, Pal. Foss., pl. xlv., f. 217, p. 115. Refigured as **Gyroceras, præclarum, T**, Whidborne, Mon. Pal. Soc. 1890, pl. viii., f. 3, p. 91.
Middle Devonian. [7001] Newton Bushel.

Cyrtoceras quindecimale, Phillips. T.
J. Phillips, Pal. Foss., pl. xliv., f. 216, p. 114; G. F. Whidborne, Mon. Pal. Soc., 1890, pl. x., f. 2, p. 102.
Middle Devonian. [7106] Newton Bushel.

Cyrtoceras reticulatum, Phillips. T.
J. Phillips, Pal. Foss., pl. xlviii., f. 224 *a*–*c*, p. 117. Refigured as **Trochoceras reticulatum**: G. F. Whidborne, Mon. Pal. Soc., 1890, pl. ix., figs. 7, 7 *a*, *b*, p. 89.
Middle Devonian. [7121] Newton Bushel.

Cyrtoceras rusticum, Phillips. T.
J. Phillips, Pal. Foss., pl. xlvi., f. 222 *a*—*c*, p. 116.
Upper Devonian. [7078] South Petherwin.

Cyrtoceras tredecimale, Phillips. T.
J. Phillips, Pal. Foss., pl. xliv., f. 215 *a*—*c*, p. 114. Refigured as **Gyroceras tredecimale**: G. F. Whidborne, Mon. Pal. Soc., 1890 pl. x., figs. 5, 5 *a*, *b*, p. 96.
Middle Devonian. [7103] Newton Bushel.

Cyrtoceras n. sp.
G. F. Whidborne, Mon. Pal. Soc., 1890, pl. xii., f. 4, p. 107.
Middle Devonian. [7105] Newton Bushel.

Goniatites globosus, Muenster.
J. Phillips, Pal. Foss., pl. l., f. 231 *a*, *b*, p. 120.
Middle Devonian. [7111] Newton Bushel.
G. F Whidborne, Mon. Pal. Soc., 1890, pl. v., figs. 12, 12 *a*, *b*, p. 67.
Middle Devonian. [7112] Newton Bushel.

Goniatites inconstans, Phillips.
G. F. Whidborne, Mon. Pal. Soc., 1890, pl. v., figs. 5, 5 *a*, p. 63.
Middle Devonian. [7113] Newton Bushel.

Goniatites insignis, Phillips. T.
J. Phillips, Pal. Foss., pl. xlix., f. 228 *a*, *b*, p. 119.
Upper Devonian. [7083] South Petherwin.

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Goniatites obliquus (Whidborne). **T,**
G. F. Whidborne, Mon. Pal. Soc., 1890, pl. v., figs. 3, 3 *a*, p. 56
Middle Devonian. [7114] Newton Bushel.

Goniatites transitorius, Phillips. **T.**
J. Phillips, Pal. Foss., pl. lx., f. 227,* p. 140 ; G. F. Whidborne, Mon. Pal. Soc., 1890, pl. v. figs. 10, 10 *a*, p. 61.
Middle Devonian. [7115] Newton Bushel.
G. F. Whidborne, Mon. Pal. Soc., 1890, pl. vi., figs. 8, 8*a*, p. 61.
Middle Devonian. [7116] Newton Bushel.

Goniatites sp.
G. F. Whidborne, Mon. Pal. Soc., 1890, pl. vi., figs. 14, 14 *a*, *b*, p. 75.
Middle Devonian. [7118] Newton Bushel.
G. F. Whidborne, Mon. Pal. Soc., 1890, pl. vi., figs. 15, 15 *a*, p. 76.
Middle Devonian. [7117] Newton Bushel.

Gyroceras armatum. *Vide* **Cyrtoceras.**

Gyroceras Crickii, Whidborne. **T.**
G. F. Whidborne, Mon. Pal. Soc., 1890, pl. x., f. 10, p. 99. (*Cyrtoceras* on plate.)
Middle Devonian. [7100] Newton Bushel.

Gyroceras Eifelense (d'Arch. and de Vern.).
G. F. Whidborne, Mon. Pal. Soc., 1890, pl. x., f. 8, p. 97.
Middle Devonian. [7097] Newton Bushel.

Gyroceras ornatum (Goldfuss, MS.), Whidborne.
G. F. Whidborne, Mon. Pal. Soc., 1890, pl. viii A., figs. 1, 1 *a*, p. 94.
Middle Devonian ? [7099] Newton Bushel ?

Gyroceras præclarum (Whidborne). **T.**
G. F. Whidborne, Mon. Pal. Soc., 1890, pl. viii., figs. 2, 2 *a*, p. 91. (See also *Cyrtoceras ornatum.*)
Middle Devonian. [7002] Newton Bushel.

Gyroceras tredecimale. *Vide* **Cyrtoceras.**

Nautilus germanus. *Vide* **Euomphalus.**

Orthoceras Champernowni, Whidborne. **T.**
G. F. Whidborne, Mon. Pal. Soc., 1890, pl. xv., f. 11, p. 142.
Middle Devonian. [7125] Newton Bushel.

Orthoceras cinctum ? J. de C. Sowerby.
J. Phillips, Pal. Foss., pl. xli., f. 204 *a*, p. 109. Refigured as **Orthoceras speciosum** (Muenster) : G. F. Whidborne, Mon. Pal. Soc., 1890, pl. xv., f. 8, p. 149.
Middle Devonian. [7134] Newton Bushel.

Orthoceras dolatum, Whidborne. **T.**
G. F. Whidborne, Mon. Pal. Soc., 1890, pl. xiv., f. 3, p. 132.
Middle Devonian. [7126] Newton Bushel.

Orthoceras ellipsoideum ? Phillips. **T.**
J. Phillips, Pal. Foss., pl. lx., f. 205,* p. 140. (*O. ventricosum*, on p. 231.) Refigured as **Poterioceras ellipsoideum** : G. F. Whidborne, Mon. Pal. Soc., 1890, pl. xi., figs. 1, 1 *a*, p. 115.
Middle Devonian. [7131] Newton Bushel.

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Orthoceras imbricatum, Hisinger.
J. Phillips, Pal. Foss.,pl. xlii., f. 207, p. 111. Refigured as **Poterioceras ?**
G. F. Whidborne, Mon. Pal. Soc., 1896, pl. iv., f. 5, p. 28.
Upper Devonian. [7079] Marwood, N. Devon.

Orthoceras laterale, Phillips.
J. Phillips, Pal. Foss., pl. xli., figs. 205 *c*, *d*, p. 110; G. F Whidborne, Mon. Pal. Soc., 1890, pl. xv., f. 3, p. 144.
Middle Devonian. [7127, 7128] Newton Bushel.
G. F. Whidborne, Mon. Pal. Soc., 1890, pl. xv., figs. 4, 5, p. 144.
Middle Devonian. [7129, 7130] Newton Bushel.

Orthoceras ludense, J. de C. Sowerby.
J. Phillips, Pal. Foss., pl. xlii., f. 206 *a*, *b*, p. 110.
Upper Devonian. [7076, 7077] (*a*) South Petherwin. (*b*) Marwood.

Orthoceras rapiforme, Sandberger.
G. F. Whidborne, Mon. Pal. Soc., 1890, pl. xiii., figs. 15, 15 *a*, p. 121.
Middle Devonian. [7132] Newton Bushel.

Orthoceras Robertsi, Whidborne. **T.**
G. F. Whidborne, Mon. Pal. Soc., 1890, pl. xiii., f. 11, p. 126.
Middle Devonian. [7133] Newton Bushel.

Orthoceras speciosum. *Vide* **O. cinctum ?**

Orthoceras subannulare (Muenster).
G. F. Whidborne, Mon. Pal. Soc., 1890, pl. xiv., figs. 7, 7 *a*, p. 138.
Middle Devonian. [7135] Newton Bushel.

Orthoceras tubicinella, J. de C. Sowerby.
G. F. Whidborne, Mon. Pal. Soc., 1890, pl. xiv., figs, 4, 4 *a*, p. 134.
Middle Devonian. [7136] Newton Bushel.

Orthoceras Vicarii (Whidborne). **T.**
G. F. Whidborne, Mon. Pal. Soc., 1890, pl. xiii., f. 3, p. 129.
Middle Devonian. [7137] Newton Bushel.

Phragmoceras ? ungulatum (Whidborne). **T.**
G. F. Whidborne, Mon. Pal. Soc., 1890, pl. xi., figs, 5, 6, 8, p. 111.
Middle Devonian. [7122-7124] Newton Bushel.

Poterioceras ellipsoideum. *Vide* **Orthoceras.**

Poterioceras ? *Vide* **Orthoceras imbricatum.**

Subclymenia Symondsi (MS.). Whidborne. **T.**
G. F. Whidborne, Mon. Pal. Soc., 1896, pl. vii., figs. 3, 3 *a*, 4, p. 26.
Marwood Beds. [7080, 7081] Braunton Down, N. Devon.

Temnocheilus inornatus (Whidborne). **T.**
G. F. Whidborne, Mon. Pal. Soc., 1890, pl. vii., figs. 3, 3 *a*, p. 80.
Middle Devonian. [7107] Newton Bushel.

Trochoceras obliquatum (Phillips).
G. F. Whidborne, Mon. Pal. Soc., 1890, pl. ix., figs. 6, 6 *a*, p. 86. (See also *Cyrtoceras.*)
Middle Devonian. [7119] Newton Bushel.

Trochoceras reticulatum. *Vide* **Cyrtoceras.**

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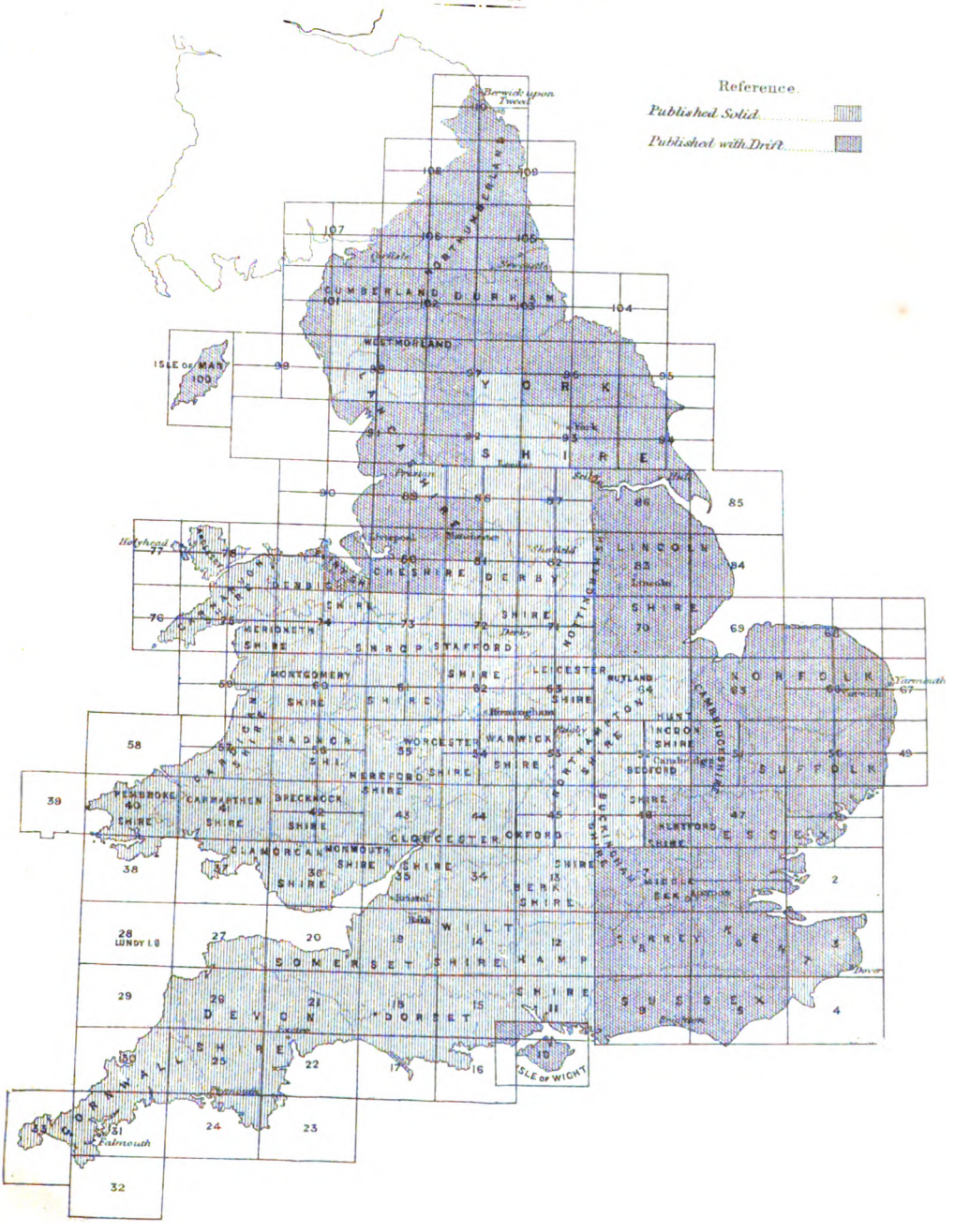

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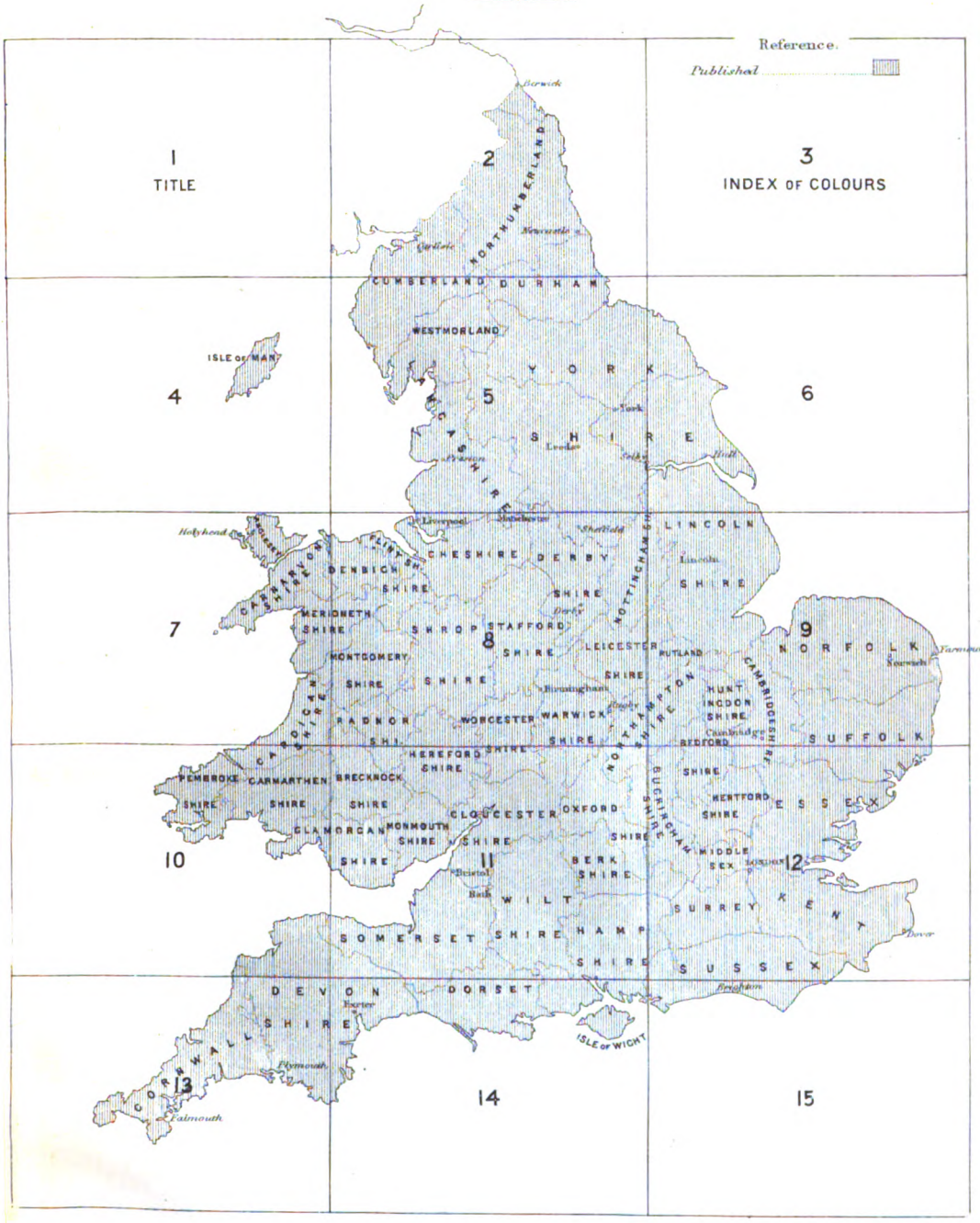

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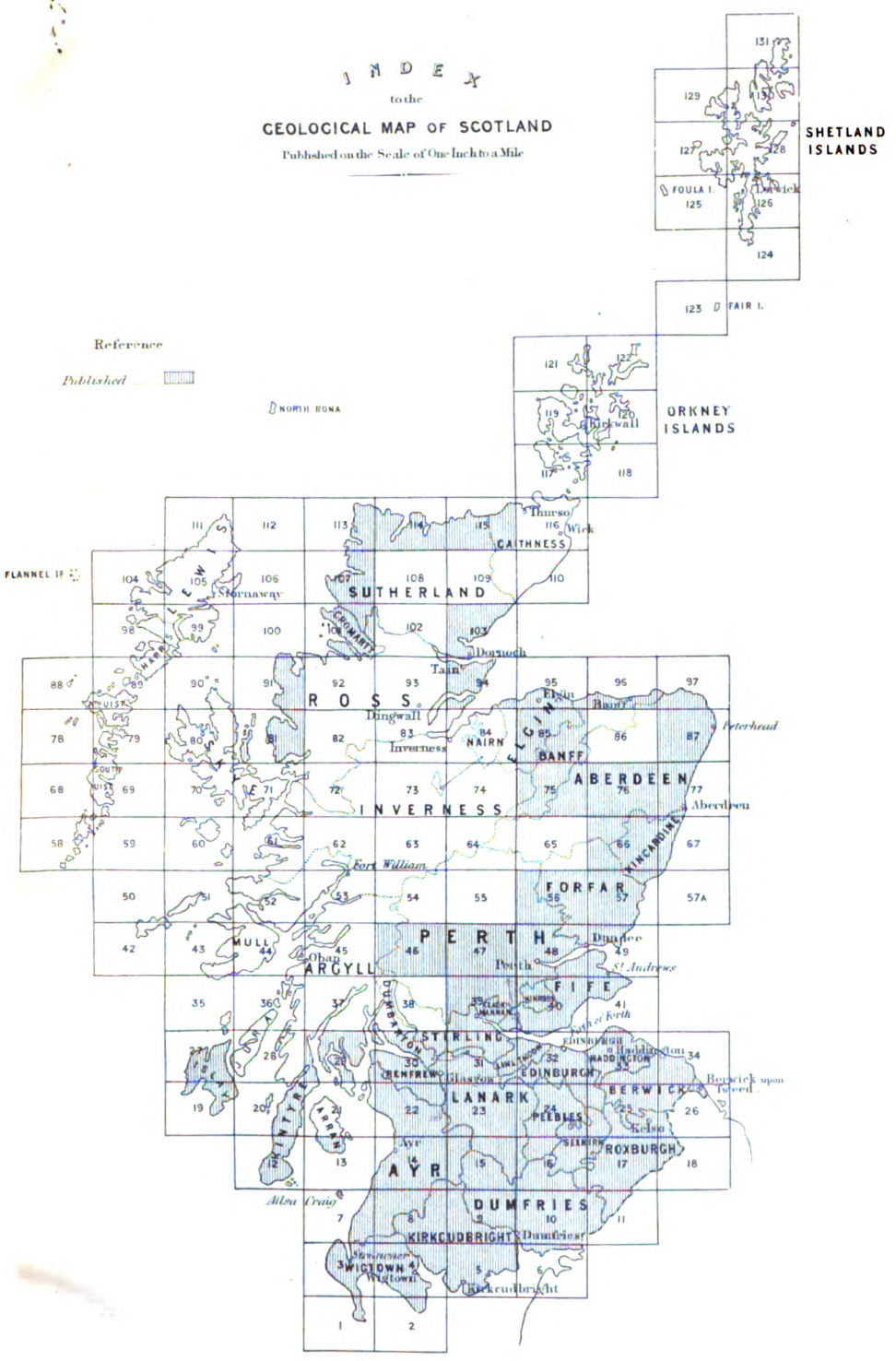

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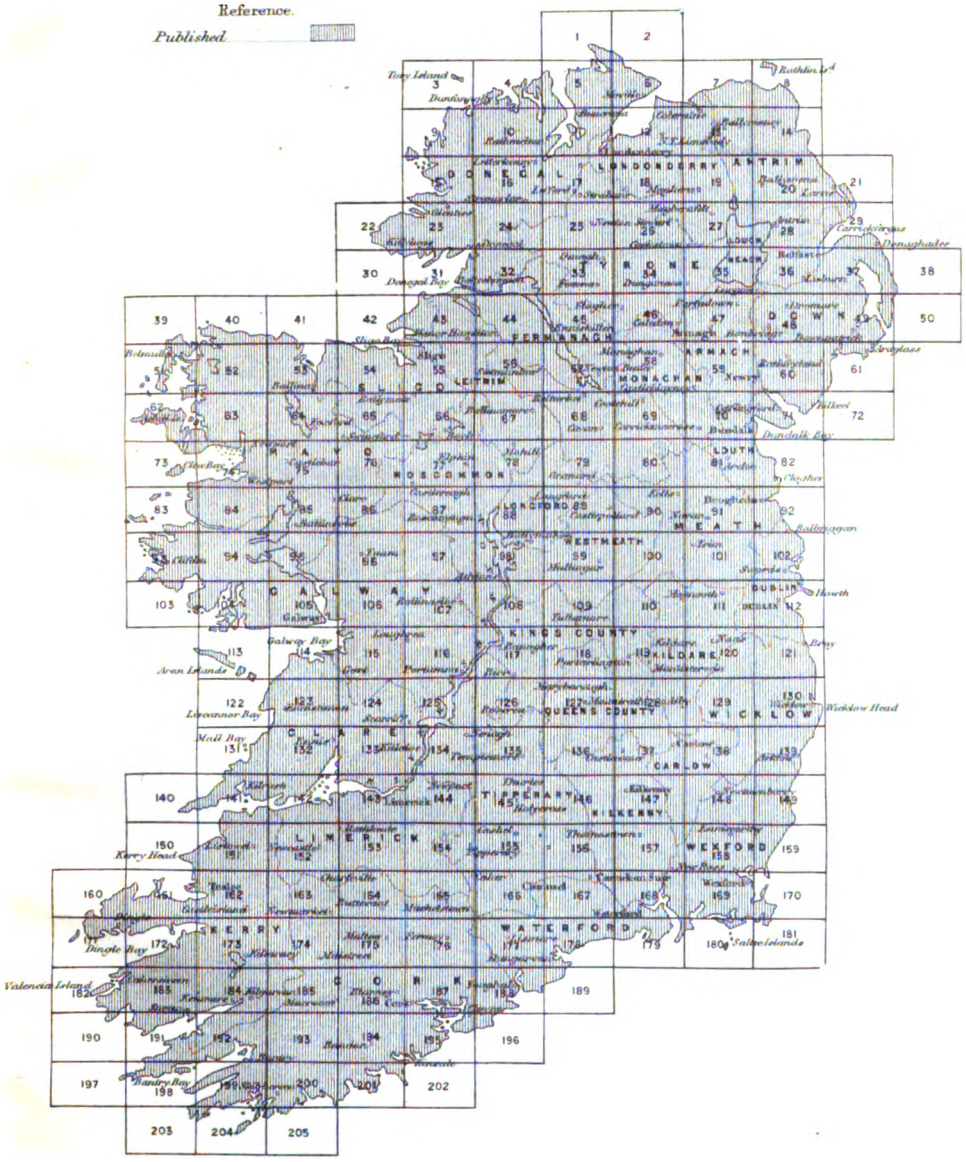

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